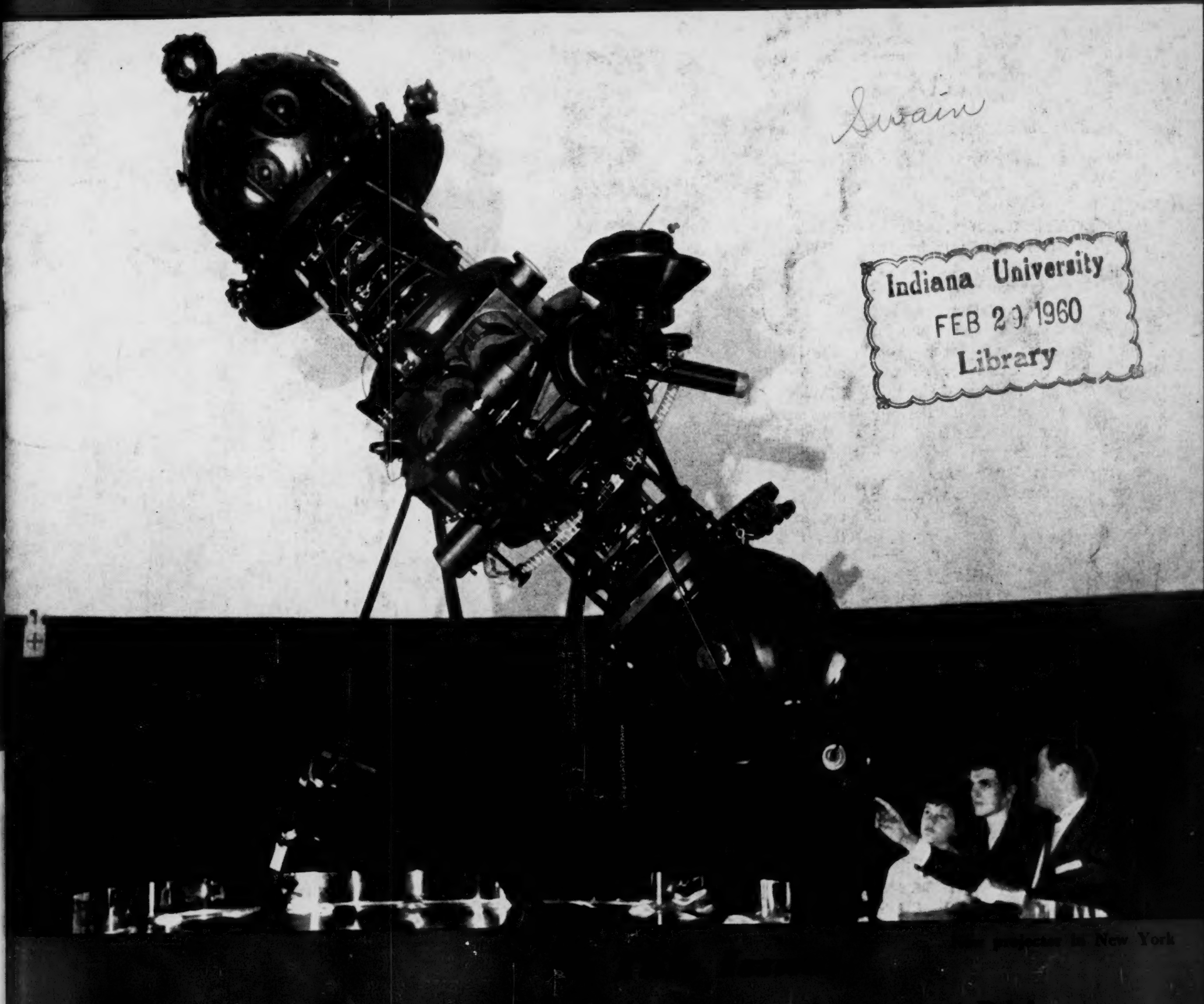
TELESCOPE



Swain

... projector in New York

Discovery

Astronomy at Brigham ... University

Peculiar ... Binary

American

Sky and TELESCOPE

CHARLES A. FEDERER, JR., *Editor*
JOSEPH ASHBROOK, *Technical Editor*

Vol. XIX, No. 5 MARCH, 1960

CONTENTS

COVER: The new Zeiss projector of the American Museum-Hayden Planetarium in New York City. Planetarium chairman Joseph M. Chamberlain (right) explains to two young visitors the features of the projector, which replaces the one that was used almost daily for 25 years. The original skyline of Central Park, cut out at the base of the planetarium dome, has been eliminated. The instrument was demonstrated to the public for the first time on January 30th, with a program entitled, "New Skies for New York." Photograph by Myles J. Adler. (See page 271.)

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LETTERS

Sir:

In my article "Radio Astronomy Receivers – II," on page 88 of the December, 1959, issue, it is stated that N. Bloembergen first proposed the possibility of maser action in solid substances. Actually, this was first advanced and proven possible by J. Combrisson, A. Honig, and C. H. Townes (*Comptes Rendus, 242,* 2451, 1956). Bloembergen's contribution was to suggest a convenient way to achieve continuous amplification, employing three energy levels, which is the method generally used at present.

FRANK D. DRAKE
National Radio Astronomy Observatory
Green Bank, W. Va.

Sir:

For about four years I have been systematically searching for variable stars, particularly in the Orion nebula. A photograph of one of my discoveries of a flare star was published on page 613 of the September, 1959, SKY AND TELESCOPE.

I am an amateur astronomer, and my work has been done under the supervision of L. Rosino, director of Padua and Asiago Observatories. My discovery, however, was not made at Padua but at my own observatory in Bologna, where I have 6-, 8-, and 12-inch reflectors, and a 4-inch photographic refractor.

I would be pleased to contact other amateurs who might be interested in cooperating in this field of research.

U. DALL'OLMO
Osservatorio Astronomico Privato
Piazza di Porta Castiglione 10
Bologna 317, Italy

Sir:

The News Note on page 147 of the January issue states that there was no sudden enhancement of atmospherics at the time of the flare pictured, on September 1, 1959.

Actually, definite SEA's were recorded at two of our official stations, operated by David Warshaw, Brooklyn, New York, and by C. H. Hossfield, Ramsey, New Jersey. The first started at 19:30 Universal time and reached maximum at 19:42; its ending was extremely gradual and indistinct. A second started at 20:12, reached maximum at 20:26, and ended at 21:02. This one was more prominent than the first.

The Solar Division's SEA patrol works with the National Bureau of Standards for the International Geophysical Cooperation (IGC-59), under a grant from the National Science Foundation.

HARRY L. BONDY
Solar Division, AAVSO
61-30 157th St.
Flushing 67, N. Y.

Reminiscences of the Discovery of Pluto

CLYDE W. TOMBAUGH, *New Mexico State University Research Center*

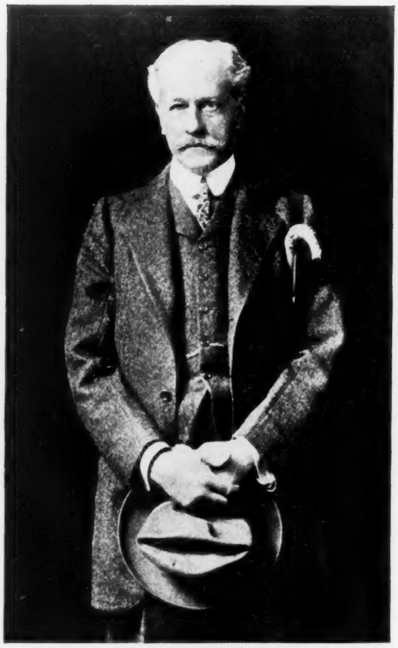
THIS YEAR marks the 30th anniversary of the finding of Pluto, farthest planet in the solar system. Yet for those who were at Lowell Observatory then, the impressions remain so vivid that it seems only yesterday. A number of people shared the many years of effort that led to this achievement. I came upon the scene on the eve of fruition of the enterprise.

Interest in the planet Mars first brought me to Lowell Observatory. Director V. M. Slipher's invitation also mentioned photographic observing, and asked, "Are you in good physical health?" Only after arriving at Flagstaff did I realize that I was to join in the search for a new planet, and what it is like to work all night long in an unheated dome in winter at 7,000 feet altitude.

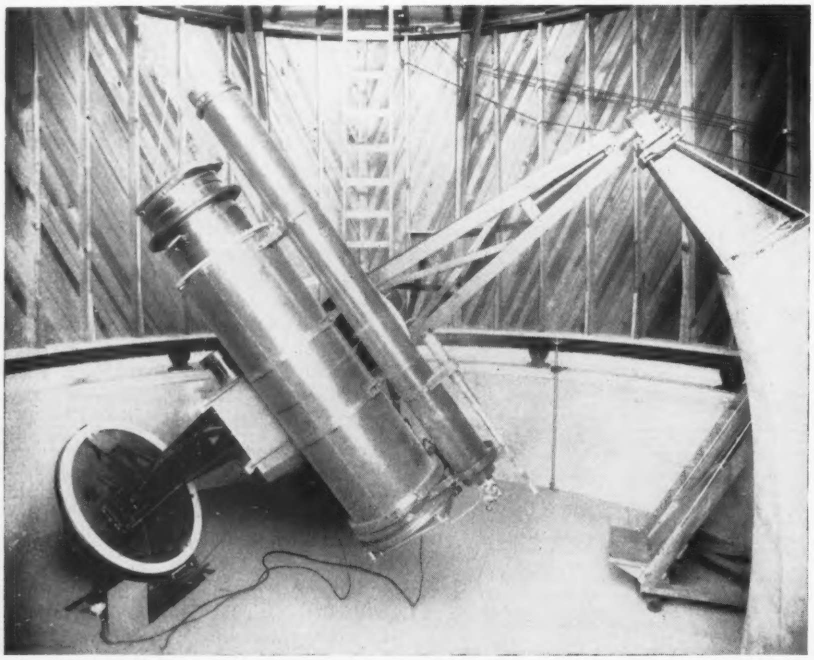
The discovery of a principal planet is not a frequent occurrence. Uranus was detected on March 13, 1781, by William Herschel as an unexpected by-product of his systematic visual search for double stars and nebulae. Its small disk caught his attention, but Herschel thought he had found a tailless comet. Nearly a year elapsed before orbit calculations by A. J. Lexell showed that the new object must be a planet. Uranus is just visible to the naked eye; and observers with telescopes had mistaken it for a star no less than 20 times in the century before Herschel's discovery. The possibility of other planets beyond Saturn seems to have occurred to few if any astronomers in those times.

The story of the finding of Neptune in 1846 is well known. Difficulties in calculating the orbit of Uranus led to a widespread suspicion that its motion was disturbed by the attraction of an unknown planet. J. C. Adams in England and U. J. J. Leverrier in France independently studied the perturbations of Uranus, and deduced the orbit, mass, and approximate position in the sky of the new planet. From this information, Neptune was promptly recognized by J. G. Galle with the 9-inch refractor of Berlin Observatory.

This was another delayed discovery, for while compiling his great star catalogue, *Histoire Céleste,* the Paris astronomer J. J. Lalande had observed Neptune on May 8 and 10, 1795. He noticed that the two positions did not agree, but discarded the first one as erroneous! He could not have had a better clue, yet 50 years were to elapse before the planet was seen again.



Percival Lowell (1855-1916) predicted mathematically the existence of a trans-Neptunian planet, and initiated the search that led to the discovery of Pluto in 1930. He was most famous for his studies of Mars.



The 13-inch Lowell refractor is carried on a two-pier equatorial mounting that is especially suitable for planet hunting, as it permits long-exposure photographs of regions near the meridian. The 7-inch guide telescope is mounted above the large main tube, while the 5-inch Cogshall camera is below it. The cylindrical dome has wooden walls. At present, all fields surveyed in the Pluto search are being rephotographed with this same telescope, in order to discover stars with large proper motions. Lowell Observatory photograph.

After Neptune's discovery, the problem of finding more remote planets became far more difficult. Perturbations of Neptune could not at first be used as a basis for prediction, since that planet had been observed over only a small part of its 165-year orbit. Instead, the starting point was the very small discrepancies between the observed and predicted motion of Uranus, after the perturbations by all known planets had been taken into account.

The most thorough treatment of this difficult mathematical problem was by Percival Lowell, the founder of Lowell Observatory. He predicted the approximate area of the sky in which to search for a hypothetical planet X. To account for the unexplained small perturbations of Uranus, he assigned a mass of seven earths and a mean distance of 43 astronomical units to the unknown object. If it were of low density and high reflecting power, like Jupiter and the other giant

planets, its apparent magnitude should have been about 12 or 13.

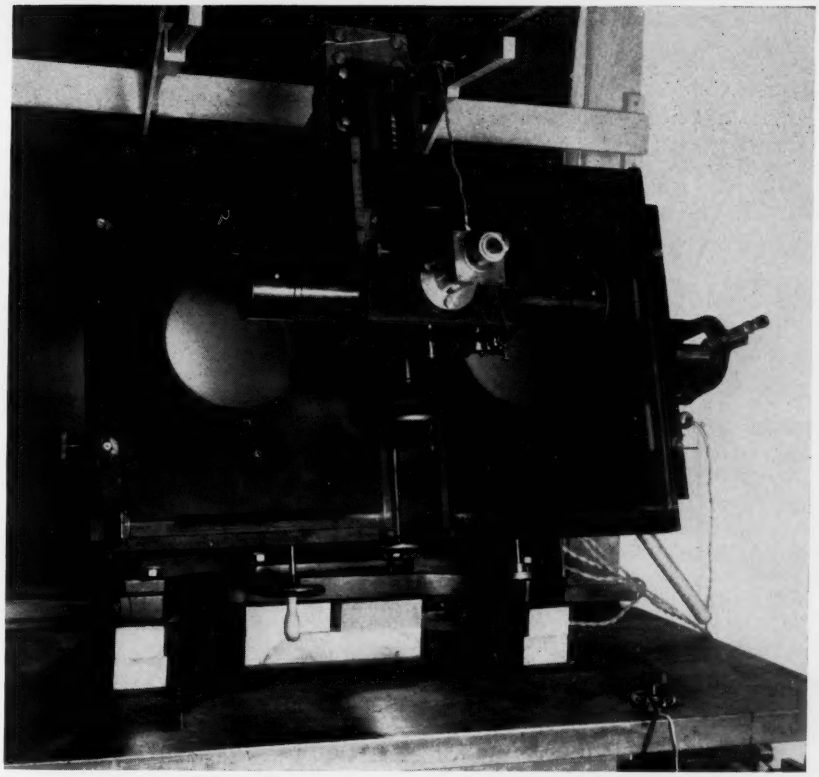
The observational problem thus proposed by Lowell was formidable, for the unknown planet could only be a faint, slow-moving body that would have to be singled out from hundreds of thousands of stars. No longer could one expect to recognize a new planet by visually checking a small sky field containing a few hundred stars.

Photography obviously provided the only efficient search technique. But at the beginning of the 20th century, photographic emulsions were less sensitive and less reliable than they are today, while modern, fast, wide-field sky cameras did not exist. Lowell Observatory began a systematic photographic search in 1905, with a 5-inch Brashear lens of 35 inches focal length. Each sky area was photographed twice, with exposures of about three hours in order to reach 16th magnitude. The plate centers were spaced about five degrees apart along the central plane of the solar system.

This intensive search from 1905 to 1907 was unsuccessful. At that time, Pluto itself was many degrees from the ecliptic, and thus outside the belt covered by the plates taken with the 5-inch camera. Pluto was also farther from the sun and hence fainter than when finally discovered in 1930; it was about magnitude 16.0, at the very limit of the 5-inch plates. At first, Lowell examined pairs of plates in physical superposition, using a hand magnifier. Later, he obtained a Zeiss blink microscope, which greatly increased the speed and thoroughness of comparing the plate pairs.

Next, an extensive series of photographs was made with the observatory's 42-inch reflector. Exposures of only a few minutes reached the 17th magnitude, but optical coma limited the telescope's useful field to about one degree, so a great number of plates had to be taken to cover the search area.

The hunt was continued from 1914 to 1916 by Lowell and C. O. Lampland, with a 9-inch Brashear lens borrowed from Sproul Observatory. Although this attempt did not result in the discovery of Pluto, it was later found that the plates actually contained weak images of the planet. Lowell's untimely death in 1916 caused a break of several years in the trans-Neptunian planet search program.

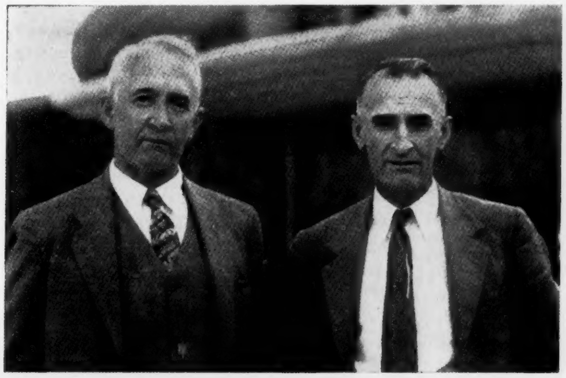


The Zeiss blink microscope used by the author. The worker looks through the eyepiece (center) at rapidly alternating views of the same star field on the two photographic plates. Any image that has moved with respect to its neighbors appears to jump back and forth. Two handles shift the pair of plates to bring the next field under scrutiny. Lowell Observatory photograph.

Meanwhile, in 1919 at Harvard Observatory, W. H. Pickering concluded a theoretical study of the motion of Neptune, from which he also predicted the existence of a planet beyond it, of about magnitude 15. At his request, the Mount Wilson Observatory's 10-inch Cooke refractor was used to take several plates of the predicted region. Faint images of Pluto were recorded on these plates, but were not recognized until after the discovery at Flagstaff.

By this time many astronomers were pessimistic about the likelihood of discovering more planets. Nevertheless, at Lowell Observatory the search was pressed by V. M. and E. C. Slipher and Lampland. To provide a more efficient instrument for the purpose, the 13-inch Lawrence Lowell photographic refractor was built, becoming ready for use by March, 1929. It had a 7-inch guide telescope.

In January of that year, I joined the Lowell Observatory staff. The 13-inch



Left: V. M. Slipher, director of Lowell Observatory during the final search for planet X. To his right is his brother, E. C. Slipher, famed for observing Mars and other planets. Photo by Clyde Fisher.

Right: C. O. Lampland shared with Percival Lowell the 1914-16 trans-Neptunian search. Here he holds a device for measuring planetary surface temperatures. Photo by Jerry McLain.

objective had not yet arrived from Carl Lundin, but the dome and mounting were nearly ready. I remember the enthusiasm of the staff members the day we opened the box and viewed this beautiful lens mounted in its cell. It had been planned that the new telescope would take 11-by-14-inch plates, but with special plateholders that bent the plates to match the focal-surface curvature, it became practical to use the 14-by-17-inch size. The focal length of the instrument was 66 inches, giving a plate scale of 30 millimeters per degree.

Many precautions were needed to insure that the plates of each pair would be accurately matched for thorough examination in the blink microscope. The outer portions of the field required constant focal curvature from plate to plate, and for this a special testing table was constructed. The limiting magnitude of the two photographs in a pair had to be closely the same.

When the observing schedule became crowded, I was obliged to use some clear nights with bad seeing. Though under favorable conditions the smallest star images were four seconds of arc in diameter, bad seeing made them soft and enlarged. Such a plate could not be blinked with another made under steadier seeing, so the second one had to be taken under similar conditions a few nights later.

The standard exposure was one hour, but in poor seeing this had to be increased by 15 to 30 minutes, in order to retrieve the loss in stellar magnitude of the expanded images. In addition, it was necessary to make the duplicate plates at about the same hour angle; otherwise, differential refraction would displace star images for areas of the plate several degrees from the guide star.

The long exposures with a lens as fast as f/5.2 caused some background fogging of the plate from the light of the sky, even on dark nights. Fortunately, bright auroras are rare at Flagstaff, but even a crescent moon above the horizon could not be tolerated. Each month, then, a week on either side of new moon was used in making exposures at the telescope. The period from first-quarter moon to last quarter was spent in blinking the plates obtained during the previous two weeks.

Clyde Tombaugh in 1931, a year after the discovery of Pluto, looking into the eyepiece of the 13-inch photographic refractor's guide telescope.

Another precaution was of paramount importance. As the earth revolves around the sun, it passes each exterior planet and causes the latter for a time to appear to move westward in the sky. This retrogression arc depends on the distance, being greatest for nearby planets, such as Mars and the asteroids, and very small for objects as far away as Neptune or beyond.

The change in direction from eastward to westward motion occurs at a stationary point, reached some time before opposition to the sun, and after opposition there is a second stationary point. While going through its stationary points, even an asteroid seems to move so slowly that for about a week it may simulate the apparent motion of a very distant planet.

Near opposition, however, a typical asteroid is in rapid westward apparent motion, and can readily be distinguished from a trans-Neptunian planet. These considerations limited the strip of sky to be searched each dark-moon period to a 30-degree extent in celestial longitude. By adhering closely to the opposition point, the daily angular shift of each planet suspect served as a quick index of its distance, since most of the apparent retrograde motion was the reflex of the earth's orbital movement.

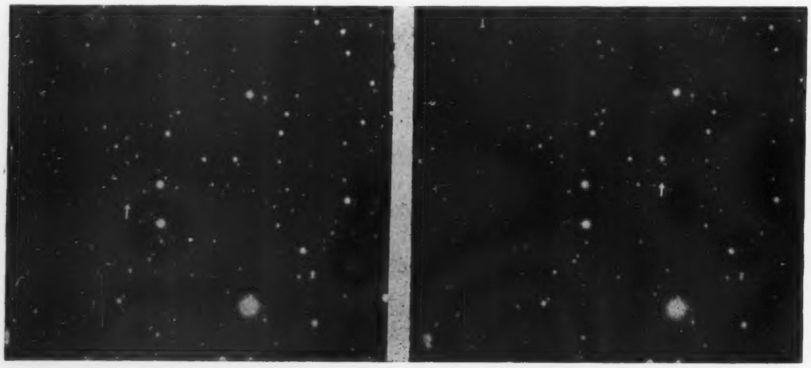
Mounted on the 13-inch telescope's tube was a 5-inch Cooke camera of about 22-inch focal length, loaned by W. A. Cogshall. Its plate scale was one centimeter per degree. When the 13-inch was in use, an exposure was made simultaneously with the 5-inch camera, affording a valuable check on suspicious objects brighter than magnitude 16.0 on the 13-inch plate.

By April, 1929, the actual observations began, with the first preliminary photographs being taken of the Gemini region, then sinking into the western sky. Although far from the opposition part of the heavens, it was the area favored by Lowell to contain his planet X. As regions farther east were observed, it became evident that most of the planet suspects were within one magnitude of the 13-inch limit and beyond the help of the 5-inch. Therefore, the practice was adopted of taking three good plates per center within a few nights of each other (preferably all three in a week). The two best-matching plates were compared in the blink microscope, and the third was available as an immediate check on any suspected moving object.

This procedure made it practical to push a thorough search well into the 17th magnitude. Chance aggregations of silver grains near the plate limit gave rise to thousands of planet suspects over the years. Each had to be checked, for the risk could not be taken of letting the long-sought planet slip by. Many suspicious images turned out to be faint variable stars whose minima were fainter than the plate limit.

That summer several astronomers passing through Flagstaff were shown the 13-inch telescope and informed of its search program. One of them said frankly that looking for trans-Neptunian planets was a waste of time and effort, since so much prior work had been without success. But we knew that the 13-inch was the best-suited instrument yet brought to bear on the problem.

During the dark of the moon, 10 to 15 hours of observing and darkroom work were required daily to run two search strips parallel to the ecliptic concurrently. Adhering strictly to the opposition regions eliminated the asteroid problem entirely, for every minor planet exhibited a definite trail during the hour exposure, and was displaced about seven millimeters per day.



Small parts of the plates that were blinked by the author on February 18, 1930, showing the discovery positions of Pluto, marked by the arrows. Note the motion of the planet between January 23 (right) and January 29, 1930. Lowell Observatory photographs.

Part of a Pluto discovery plate. This region near Delta Geminorum (the bright star inside a halation ring) has been enlarged three times from the original negative taken with the 13-inch telescope on January 29, 1930. Pluto is between the two short vertical lines. One of the small pictures on the facing page is from this plate.

As the autumn of 1929 came, the perfected technique of observing and blink examination had settled into routine. When the plates were well matched and reasonably clean of spurious images, I could carry out six or seven hours of actual blinking each day. In Pisces and Aries, each plate recorded some 50,000 stars, and a pair could be examined in three days. These plates were a delight to scan, with hundreds of images of beautiful spiral galaxies.

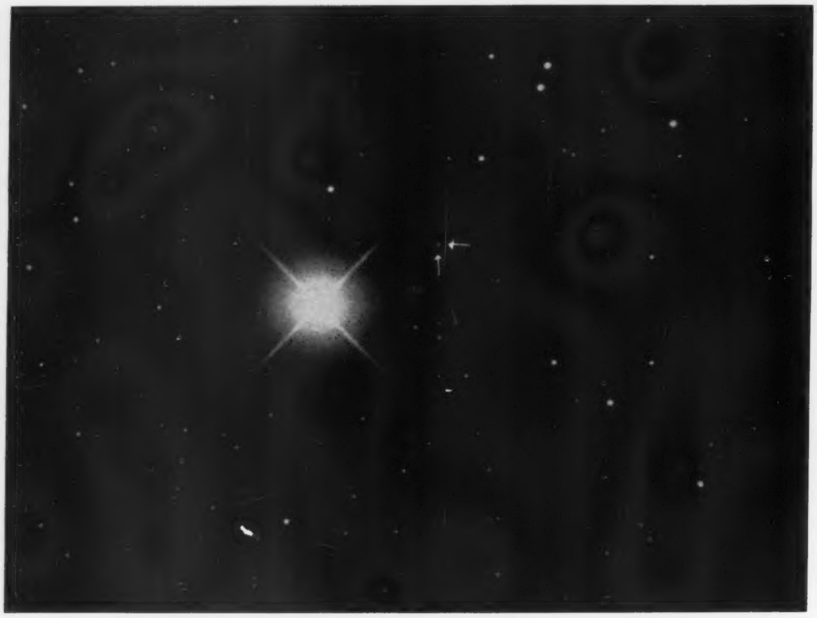
The number of star images gradually increased as the Milky Way was approached. The plates of eastern Taurus and western Gemini contained up to 400,000 stars each! These had to be examined in small groups of only a dozen stars at a time. For very rich regions, it was necessary to use narrow rectangular diaphragms to limit the maze of stars. Therefore, the speed of examination decreased as these rich star regions were encountered, and the work with the blink comparator began to fall behind schedule.

In February, 1930, after struggling through the Taurus plates, I skipped over to those in eastern Gemini, where the stars were less thickly packed. The entire length of the latter constellation had been photographed by the end of January that year. I chose three plates centered on Delta Geminorum, taken January 21st, 23rd, and 29th, respectively, but bad seeing made the first of these unacceptable for blinking.

I placed the other two in the comparator and began blinking the east half from the south end. By 4:00 p.m. on February 18th, one-fourth of the plate area had been blinked. Upon turning to a new eyepiece field two-thirds of a degree east of Delta, I suddenly spied a 15th-magnitude object popping in and out of the background. Just 3½ millimeters away another 15th-magnitude image was doing the same thing, but appearing alternately with respect to the other, as first one plate and then the second was visible through the eyepiece.

"That's it!" I exclaimed to myself. The change in position — only three or four millimeters in six days — was much too small for an ordinary asteroid near opposition. But were the images real or spurious? At once I laid out the 8-by-10-inch plates that had been taken by our Cogshall camera simultaneously with the 13-inch exposures. Although nearly at its limit of visibility, there were the images exactly in the same respective positions!

With mounting excitement, I got out the January 21st plates and quickly checked them with a hand magnifier. Even though the 13-inch plate was a sorry one, there was the image displaced about one millimeter east of the January 23rd position, and it was confirmed on the 5-inch exposure. Any possibility of the phenomenon being a pair of variable stars was now ruled out. Next, I measured the displacements approximately



After Pluto's discovery, C. O. Lampland used the Lowell Observatory 42-inch reflector to obtain precise positions for orbit computations. In this photograph of March 4, 1930, the bright star is Delta Geminorum.

with a millimeter scale. The object was retrograding about 70 seconds of arc per day. This seemed to be it!

Dr. Lampland was in his office across the hall. At 4:45 p.m., I told him that I had found something, and he came in and sat down at the comparator. Then I went to the director's office to inform Dr. Slipher, who hurried down the hall to the comparator room. (The other staff member, E. C. Slipher, was not in the building.) The two astronomers repeated the same checks for their satisfaction. The air was tense with excitement.

We looked through the window. The sky was very cloudy – no chance of getting a recovery plate that evening. Dr. Slipher stressed that no announcement should be made until observational confirmation was completed during the next few weeks.

I was a young bachelor then, and generally left the observatory at 5 p.m. to go downtown for dinner. But it must have been after six o'clock when we dispersed from the comparator room. I could hardly eat for thinking about the images. I remember that because the evening was cloudy, I went to the movies and saw Gary Cooper in The Virginian. After the gun-drawing act, I came out tenser than ever. It was still cloudy.

The next night, February 19th, was clear, and another one-hour exposure of the Delta Geminorum region could be taken. I developed the plate and left it on the drying rack to be ready for blinking the next morning with one of the discovery pair. Although three weeks had elapsed, the new image was quickly found about one centimeter west of the January 29th position.

From this plate, a contact film was made to serve in locating the planet visually with the 24-inch refractor. On the following evening, we gathered in the dome. The important question was whether the distant object would show a disk. The big telescope was turned to Delta Geminorum, and with the aid of the finder chart we identified the faint field stars where the planet should be. There it was, a most unimportant-looking, dim, starlike object, which had moved perceptibly from its plate position of the night before. Each of the staff took a look. No disk could be made out, even though the seeing was fairly good. This caused some uneasiness, for Lowell had predicted a disk one second of arc in diameter and a stellar magnitude of 12.

For the next few weeks, the new planet was photographed every possible night by Dr. Lampland with the 42-inch reflector, to obtain precise positions. Exposures of only seven minutes gave good images. In addition, he made a pair of one-hour exposures, reaching to magnitude 19, in an unsuccessful search for possible satellites of the new object. His photographs through blue and yellow filters indicated

LOWELL OBSERVATORY

Observation Circular

THE DISCOVERY OF A SOLAR SYSTEM BODY APPARENTLY TRANS-NEPTUNIAN

The message sent last night (March 12) to Harvard Observatory for distribution to astronomers read as follows:

"Systematic search begun years ago supplementing Lowell's investigations for TransNeptunian planet has revealed object which since seven weeks has in rate of motion and path consistently conformed to Trans-Neptunian body at approximate distance he assigned. Fifteenth magnitude. Position March twelve days three hours GMT was seven seconds of time West from Delta Geminorum, agreeing with Lowell's predicted longitude."

(For ease in finding object was referred to Delta Geminorum. Position March 12.14 G.M.T. R.A. $7^h\ 15^m\ 50^s$ Dec. 22° 6′ 49″)

The finding of this object was a direct result of the search program set going in 1905 by Dr. Lowell in connection with his theoretical work on the dynamical evidence of a planet beyond Neptune. (See L. O. Memoirs, Vol. I, No. 1, "A Trans-Neptunian Planet," 1914). The earlier searching work, laborious and uncertain because of the less efficient instrumental means, could be resumed much more effectively early last year with the very efficient new Lawrence Lowell telescope specially designed for this particular problem. Some weeks ago, on plates he made with this instrument, Mr. C. W. Tombaugh, assistant on the staff, using the Blink Comparator, found a very exceptional object, which since has been studied carefully. It has been photographed regularly by Astronomer Lampland with the 42-inch reflector, and also observed visually by Astronomer E. C. Slipher and the writer with the large refractor.

The new object was first recorded on the search plates of January 21 (1930), 23rd, and 29th, and since February 19 it has been followed closely. Besides the numerous plates of it with the new photographic telescope, the object has been recorded on more than a score of plates with the large reflector, by Lampland, who is measuring both series of plates for positions of the object. Its rate of motion he has measured for the available material at intervals between observations with results that appear to place the object outside Neptune's orbit at an indicated distance of about 40 to 43 astronomical units. During the period of more than 7 weeks the object has remained close to the ecliptic; the while it has passed from 12 days after opposition point to within about 20 days of its stationary point. Its rate of retrogression, March 10 to 11, was about 30″ per day. In its apparent path and in its rate of motion it conforms closely to the expected behavior of a Trans-Neptunian body, at about Lowell's predicted distance. There has not been opportunity yet to complete measurements and accurate reductions of positions of the object requisite for use in the computation of the orbit, but it is realized that the orbital elements are much to be desired and this important work is in hand.

In brightness the object is only about 15th magnitude. Examination of it in the large refractor—but without very good seeing conditions—has not revealed certain indication of a planetary disk. Neither in brightness nor apparent size is the object comparable with Neptune. Preliminary attempts at comparative color tests photographically with large reflector and visually with refractor indicate it does not have the blue color of Neptune and Uranus, but hint rather that its color is yellowish, more like the inner planets. Such indications as we have of the object suggest low albedo and high density. Thus far our knowledge of it is based largely upon its observed path and its determined rates of motion. These with its position and distance appear to fit only those of an object beyond Neptune, and one apparently fulfilling Lowell's theoretical findings.

While it is thus too early to say much about this remarkable object and much caution and concern are felt—because of the necessary interpretations involved—in announcing its discovery before its status is fully demonstrated; yet it has appeared a clear duty to science to make its existence known in time to permit other astronomers to observe it while in favorable position before it falls too low in the evening sky for effective observation.

—V. M. SLIPHER.

Flagstaff, Arizona
March 13, 1930

that the planet was yellowish, resembling the terrestrial planets and unlike Uranus and Neptune, which are bluish.

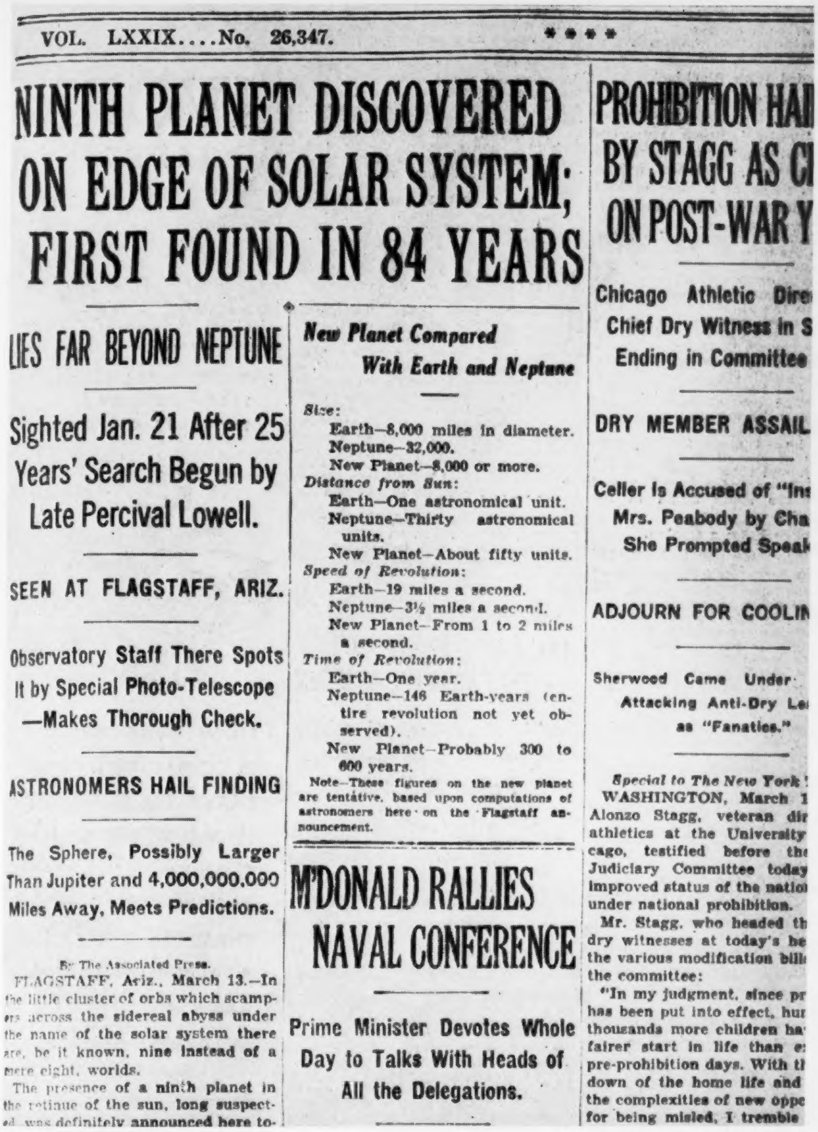
Possibly then, the new planet was quite dense. Even if its faintness was caused by low reflectivity rather than small size, an improbably high density seemed required to give the planet its predicted mass. Was the new object not Lowell's planet X after all, but some interloper?

E. C. Slipher undertook an experiment to clarify this. On the mesa just northeast of Flagstaff, he placed a box containing a source of light and having small holes of different sizes cut in one side. He viewed these with the 24-inch refractor and found, at the very low level of illumination resembling that prevailing on the actual planet, that a hole could subtend an angle of half a second of arc and still escape recognition as a disk.

As the weeks passed, the motion of the object conformed perfectly to that expected of a trans-Neptunian planet. It was decided to announce the discovery on March 13, 1930, which was the 75th anniversary of Percival Lowell's birth, and the date of Uranus' discovery 149 years earlier. Late on the night of the 12th, director V. M. Slipher sent a telegram to the Harvard Observatory clearinghouse for official distribution.

Next day the news spread out over the world. Soon newspaper and magazine reporters arrived in Flagstaff and swarmed over the observatory on Mars Hill. Letters and telegrams poured in, containing congratulations and suggesting names for the new planet. Around the observatory all other work was disrupted. Observers at other institutions quickly confirmed the position and motion of the new planet.

Of the names suggested, the three most popular were Pluto, Minerva, and Cronus. However, one of the asteroids had already been called after Minerva, the goddess of wisdom. Pluto was better known, and his



VOL. LXXIX....No. 26,347. * * * *

NINTH PLANET DISCOVERED ON EDGE OF SOLAR SYSTEM; FIRST FOUND IN 84 YEARS

LIES FAR BEYOND NEPTUNE

Sighted Jan. 21 After 25 Years' Search Begun by Late Percival Lowell.

SEEN AT FLAGSTAFF, ARIZ.

Observatory Staff There Spots It by Special Photo-Telescope —Makes Thorough Check.

ASTRONOMERS HAIL FINDING

The Sphere, Possibly Larger Than Jupiter and 4,000,000,000 Miles Away, Meets Predictions.

By The Associated Press.

FLAGSTAFF, Ariz., March 13.—In the little cluster of orbs which scampers across the sidereal abyss under the name of the solar system there are, be it known, nine instead of a mere eight, worlds.

The presence of a ninth planet in the retinue of the sun, long suspected was definitely announced here to-

New Planet Compared With Earth and Neptune

Size:
Earth—8,000 miles in diameter.
Neptune—32,000.
New Planet—8,000 or more.

Distance from Sun:
Earth—One astronomical unit.
Neptune—Thirty astronomical units.
New Planet—About fifty units.

Speed of Revolution:
Earth—19 miles a second.
Neptune—3½ miles a second.
New Planet—From 1 to 2 miles a second.

Time of Revolution:
Earth—One year.
Neptune—146 Earth-years (entire revolution not yet observed).
New Planet—Probably 300 to 600 years.

Note—These figures on the new planet are tentative, based upon computations of astronomers here on the Flagstaff announcement.

M'DONALD RALLIES NAVAL CONFERENCE

Prime Minister Devotes Whole Day to Talks With Heads of All the Delegations.

PROHIBITION HAI BY STAGG AS CI ON POST-WAR Y

Chicago Athletic Dire Chief Dry Witness in S Ending in Committee

DRY MEMBER ASSAIL

Celler Is Accused of "Ins Mrs. Peabody by Cha She Prompted Speak

ADJOURN FOR COOLIN

Sherwood Came Under Attacking Anti-Dry Le as "Fanatics."

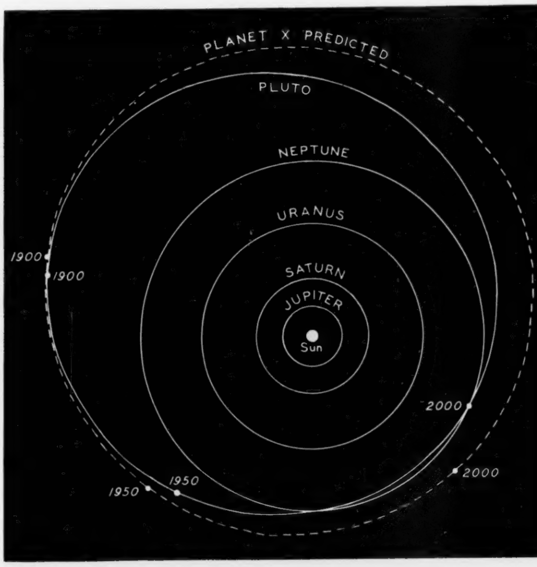
Special to The New York

WASHINGTON, March 1 Alonzo Stagg, veteran dir athletics at the University cago, testified before the Judiciary Committee today improved status of the natio under national prohibition.

Mr. Stagg, who headed th dry witnesses at today's he the various modification bill the committee:

"In my judgment, since pr has been put into effect, hur thousands more children ha fairer start in life than e pre-prohibition days. With tl down of the home life and the complexities of new oppc for being misled, I tremble

The New York "Times" front-page Pluto story on March 14, 1930.

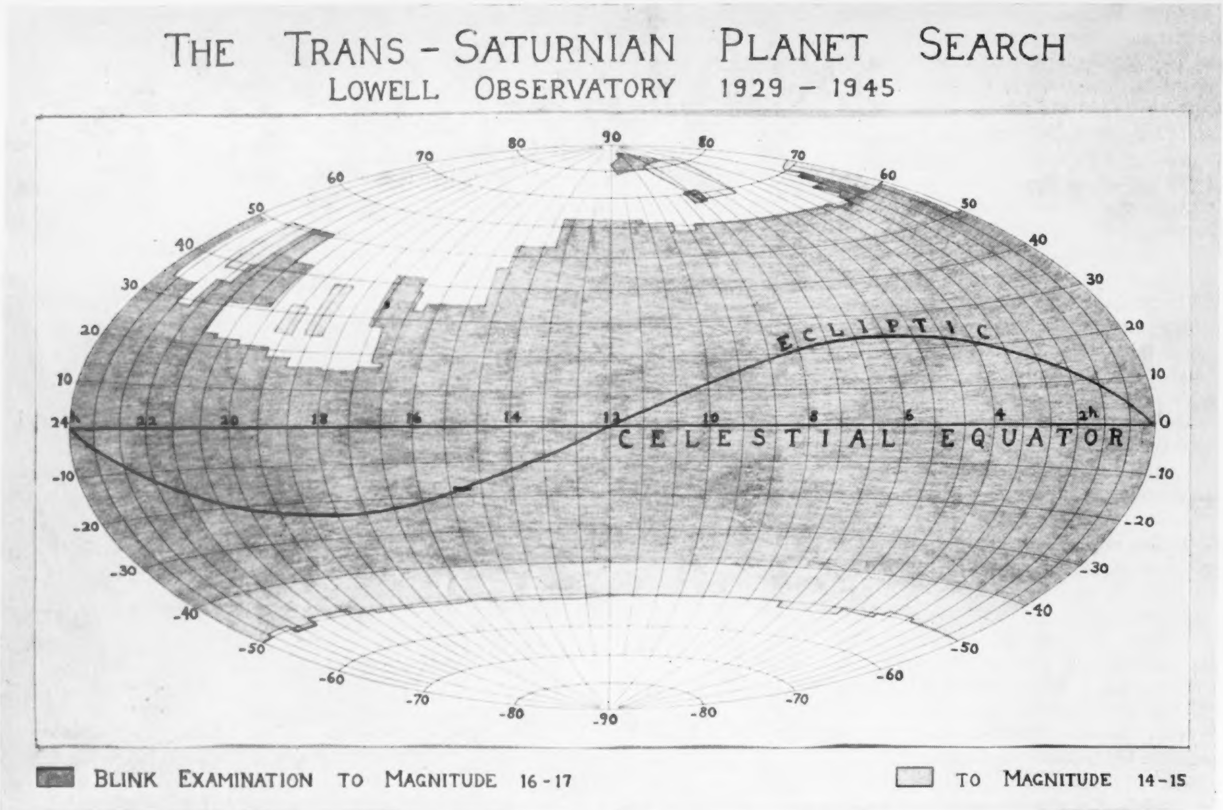


Here Percival Lowell's predicted orbit of planet X is compared with the observed orbit of Pluto. At the time of discovery, Pluto was close to its anticipated distance from the sun, but slightly ahead of its predicted position. Current values give 248 years for Pluto's period of revolution, and 39.5 astronomical units for its mean distance from the sun. Pluto can pass inside the orbit of Neptune, but the tilt between their orbit planes prevents collision.

two brothers Jupiter and Saturn were already in the heavens. In early May, the name Pluto was selected by Lowell Observatory and officially proposed to the American Astronomical Society and to the Royal Astronomical Society. For the planetary symbol, the interlocked letters P and L were chosen, being both the first two letters of the planet's name and Percival Lowell's initials.

Could the systematic search techniques by which Pluto was found lead to other discoveries of distant planets? Dr. V. M. Slipher encouraged me to continue the hunt with the 13-inch telescope entirely around the sky, and to a considerable distance from the ecliptic. This program was long and difficult. Later, Frank Edmondson and Henry Giclas gave invaluable assistance taking high-quality plates, and the blinking was carried out by me.

By 1943, a major part of the sky had been combed for planetary bodies down



On this sky map are indicated the regions covered by Lowell Observatory's survey. Nearly the entire sky from declination −50° to +50° has been investigated for faint, distant planets. Lowell Observatory chart.

to the 16th and 17th magnitudes. No new planet suspects were found, though one 16th-magnitude object was noted whose apparent motion matched Uranus' distance from the sun. More plates failed to pick it up. The original pair had been taken a little far from the opposition area, and the object may have been an asteroid near its stationary point.

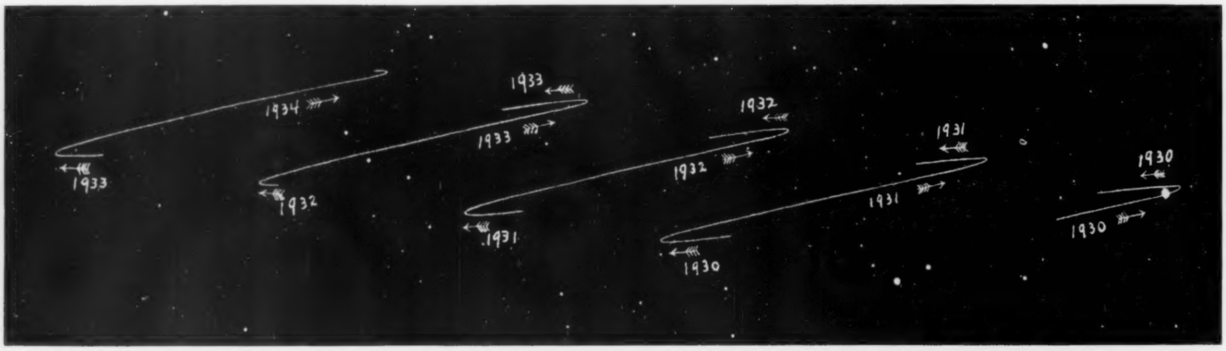
This survey was planned so that bodies as close as Saturn could have been detected, a generous overlap of plate regions being chosen to allow for their more rapid motions. The time interval between the plates of each pair was enough to reveal the motion of an object 10 times as remote as Pluto. On the one-hour exposures, a planet like Jupiter could have been recognized at 450 astronomical units from the sun, or one like Neptune at 270.

In addition, during 1939 and 1940 a series of 2½-hour plates was taken along the ecliptic to extend the planet search to magnitude 18. In the Milky Way, however, the stars were so numerous that the examination of the plates became prohibitively tedious. Three to four weeks of intensive work was required to blink a single pair. In Scorpius and Sagittarius even one-hour exposures recorded a million stars on each plate!

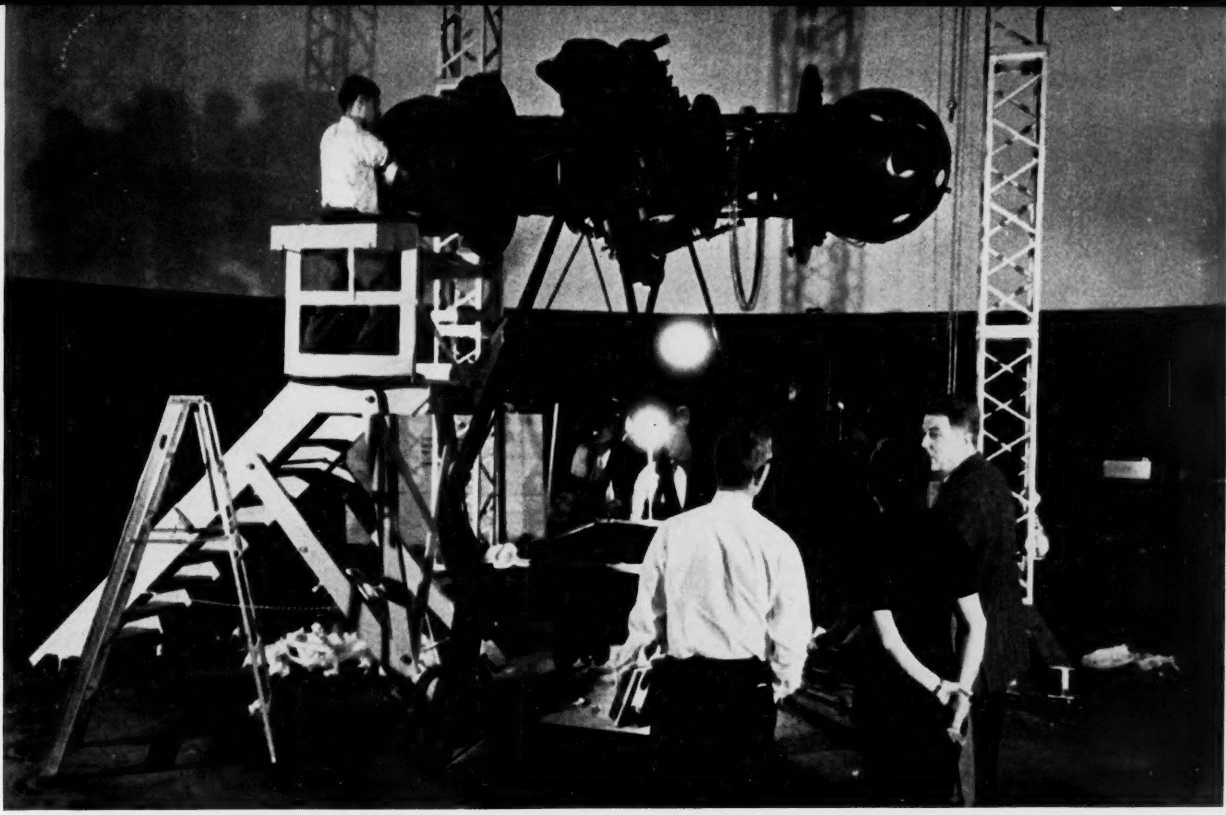
Shortly before World War II, Lowell Observatory decided to acquire a 25-inch f/4 Schmidt camera to extend the search to the 19th magnitude. But the pressures of the war intervened, and the hunt for fainter planets was never resumed.

During my share of Lowell Observatory's long-continued searching for trans-Neptunian planets, about 90 million star images were examined in 7,000 hours at the blink comparator. Nearly 4,000 asteroid images were marked on the plates, 40 per cent of them new, while 1,807 variables were noted, and 29,548 galaxies were counted. One new globular and six galactic star clusters were by-products of the search. Only one comet was found, on a pair of plates taken a year earlier.

It seems safe to conclude from the Lowell surveys that no unknown planet beyond Saturn exists that was brighter than magnitude 16½ at the time of search.



The motion of Pluto as seen on the sky is traced from 1930 to 1934. The bright star on the right is Delta Geminorum, and the star cluster NGC 2420 appears just below the starting point of the observing period that began late in 1931.



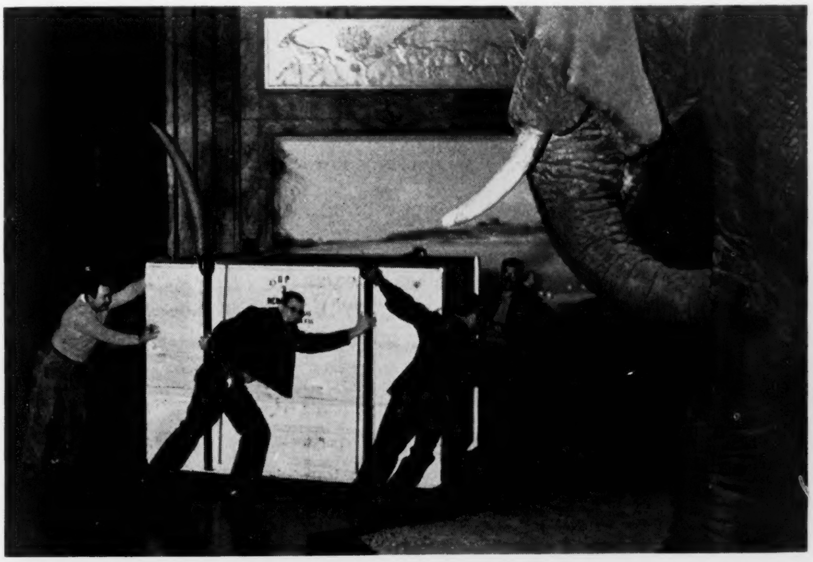
Staff members of the American Museum-Hayden Planetarium watch the assembly of their new Zeiss projector. Since October, 1935, 10 million visitors had seen the original instrument in action. Photograph by Myles J. Adler.

Two Eastern Planetariums Re-equipped

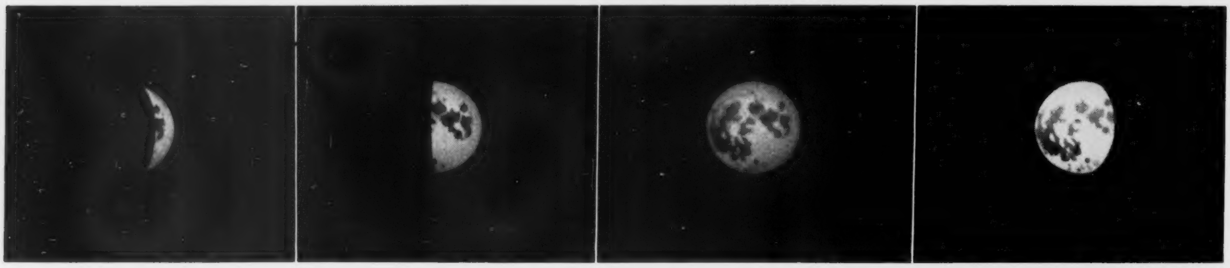
MAJOR CHANGES have recently been made at the Morehead Planetarium, Chapel Hill, North Carolina, and at the American Museum-Hayden Planetarium in New York City. For the first institution, supplementary equipment worth $30,000 was installed on the star projector, while for the second an entirely new Zeiss instrument, incorporating all these modernizations, was purchased to replace the original projector.

The Chapel Hill improvements were made possible by a gift from John M. Morehead, original donor of the planetarium. Manager Anthony F. Jenzano visited the Carl Zeiss Works at Oberkochen, West Germany, to watch the manufacture of the new parts and to learn how to incorporate them into the instrument. On his return to North Carolina, the assembly took only 17 days, and was finished on November 15, 1959. He and the planetarium staff did most of the work. The planet cages, which were fitted with new projectors, were milled and reinforced in the machine shop of the University of North Carolina's physics department.

To show the brightest stars, both the Chapel Hill and New York planetariums now have 42 individual projectors, mounted on ruffs just below the north and south star balls. Prewar instruments had projected these stars as larger but not brighter than the faint ones, and their extended disks detracted from the realism of the sky. The largest of the new images is only about an inch in diameter. In addition, the variable stars Algol, Mira, and Delta Cephei are portrayed by means of automatic devices that give exact reproductions of their light variations, but



One of 13 crates used to ship parts of the new projector from Germany is being carted through the Akeley African hall of the American Museum of Natural History. Photograph by Myles J. Adler.



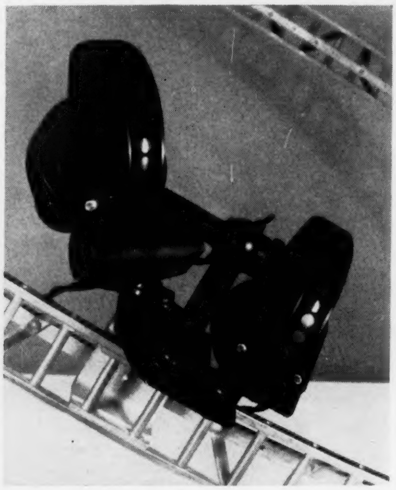
The planetarium moon now has surface features like those seen with the naked eye on the moon itself. With the aid of aluminized glass mirrors, the moon projector produces a brighter image. Carl Zeiss Studio photograph.

on a suitably compressed time sequence.

Further Hayden modifications included replacing the 733 old wooden seats with more than 800 theater-type ones, and removing the 25-year-old Manhattan skyline. Now 14 projectors located around the periphery of the dome allow the skyline to be changed at will. New seats were also installed in the room of the Copernican planetarium on the first floor of the building.

Since the projector at New York had begun to wear out after almost a quarter-century of continuous service, it was de-

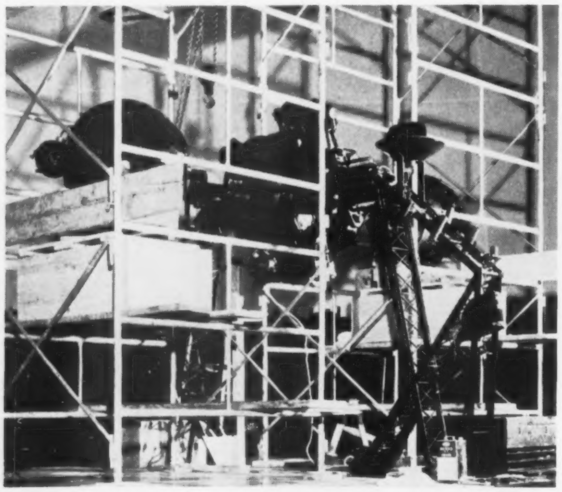
In North Carolina's Morehead Planetarium, manager Anthony F. Jenzano inspects parts for the new ruffs that carry the bright-star projectors.



To demonstrate the celestial or nautical triangle, these projectors produce a vertical circle (left) and an hour circle (right). They are mounted on the skeleton ring for the mean sun.

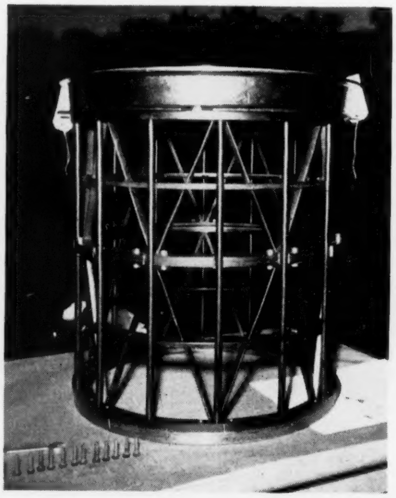
cided to replace it entirely with one of the new Mark III instruments. These are already in use at Hamburg, Tokyo, Sao Paulo, and London (Sky and Telescope, July, 1958, page 440). This is the 33rd Zeiss projector, and cost $150,000 – only $25,000 more than paid for the first Hayden instrument in 1935.

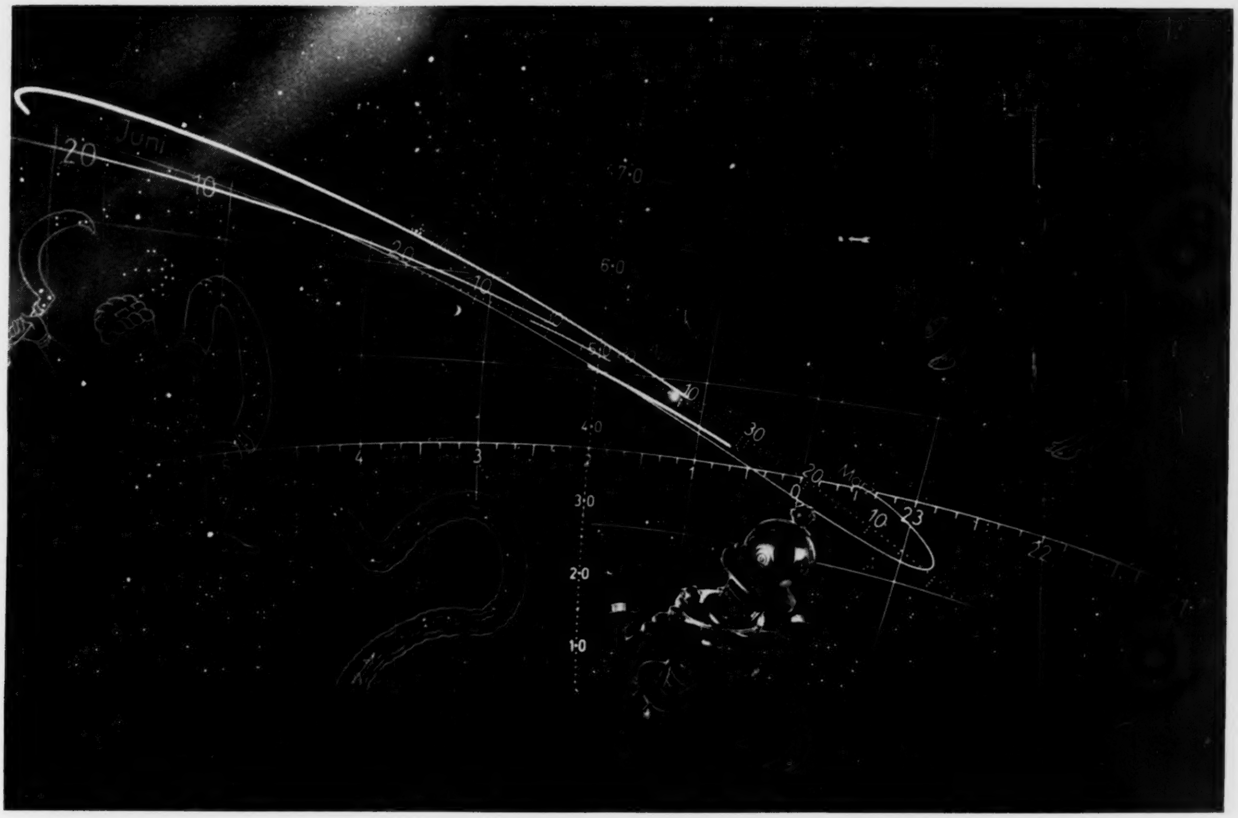
With the new projector, it is possible to demonstrate the daily motion of the sky in three, four, six, or 12 minutes, while



Left: During the first stage of the work at Chapel Hill, this scaffolding was erected to support the heavy parts of the instrument. The cages containing the planet projectors have been removed.

Right: Reassembly began with the milled and strengthened cages. The southern one is shown here. Note the added interlacing supports. University of North Carolina photographs.





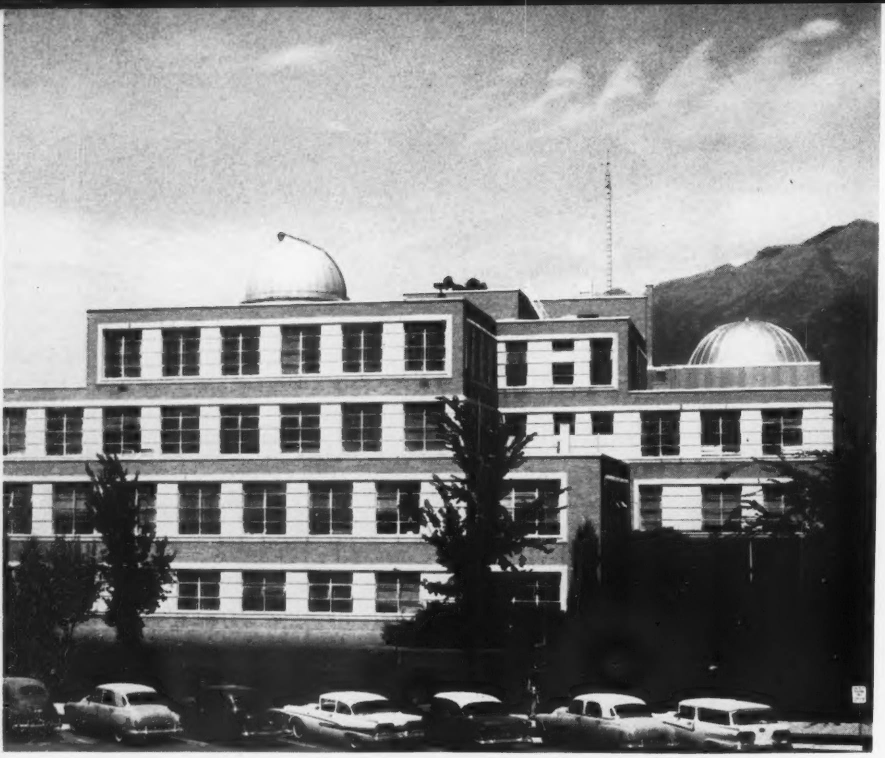
the annual motions of the sun, moon, and planets can be shown at these rates or at the high speed of one year in 10 seconds. The 8,900 stars fainter than 2nd magnitude are produced by 32 projectors, their chromium star plates having been perforated by a new photochemical process.

The installation in New York took four weeks, the Hayden staff having the help of an engineer and three technicians from the Zeiss factory. Working 24 hours a day, they erected the 2½-ton, 17-foot-high device in record time. Composed of 159 optical projectors and seven motors, and embodying over 29,000 parts, the Mark III has fiber and steel gears that insure smooth and quiet operation.

Above: In one view of the sky as projected by a new Zeiss instrument are the fixed stars, some constellation figures, the sun, moon, and geocentric planet paths. Also shown are the meridian, ecliptic, equator, celestial co-ordinate grid, and an arrow produced by the lecturer's pointer.

Right: This projector demonstrates the annual aberration and parallax ellipses traced in the sky by Sirius, one of the nearest stars.

Below: Exterior view (left) and interior view of the southern ruff, showing the special projectors for bright stars. All photographs on this page are by the Carl Zeiss Studio.



Atop Eyring Science Center of Brigham Young University, the dome at the left is 22 feet in diameter and houses the 24-inch reflector pictured below. At the right is the dome of the Summerhays Planetarium, which has a Spitz projector. Brigham Young University photographs.

Astronomy at Brigham Young University

D. H. McNamara, *Physics Department, Brigham Young University*

SINCE the dedication of our planetarium in January, 1958, the number of students taking elementary astronomy at Brigham Young University has increased to 750, compared with 300 several years ago.

Now we have added a 24-inch reflecting telescope, a versatile instrument with a photoelectric photometer and a Baker corrector for wide-angle photography. This marks the beginning of a new era in astronomy in this area, for it is the first major telescope to be erected in Utah. Our university is now well equipped to serve the public, the student body, and the student of astronomy who has a serious interest in research.

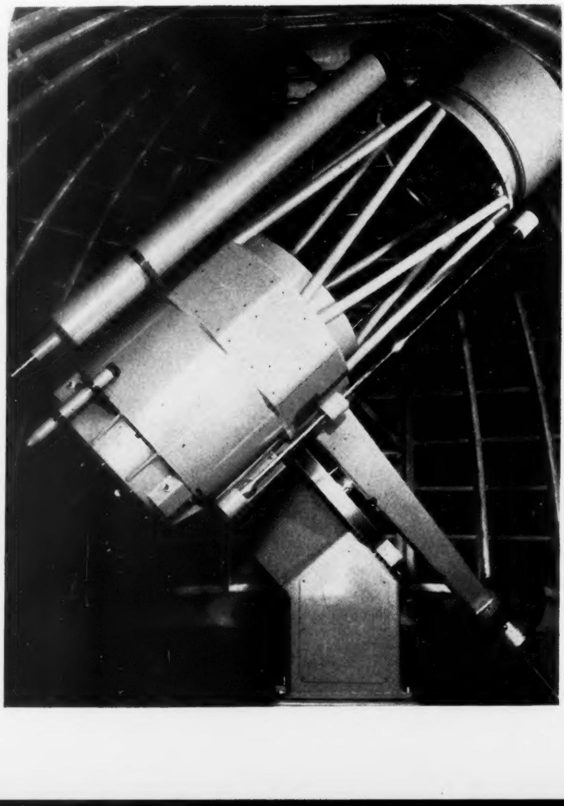
The university's campus is at Provo, 45 miles south of Salt Lake City. The planetarium was erected on the roof of the physical science building, in which a Foucault pendulum and exhibits of the chemistry and geology departments are also accessible to visitors. The planetarium was provided by a gift from the Hyrum B. Summerhays family of Bountiful, Utah, in order to bring astronomy to both students and townspeople. Several thousand persons have attended the weekly public lectures. Church, school, and civic groups come from as far away as 250 miles to special showings.

The planetarium dome has an inside diameter of 24 feet, with the Utah Valley horizon simulated in an artificial skyline. This is set six inches out from the dome itself, with sunrise and sunset lights behind. A slightly modified Spitz A-2 projector provides the star images.

The science center was built in 1950, and a 5-inch refractor in a 22-foot dome placed on the roof. That instrument has now been replaced by the 24-inch reflector, which is housed in the same dome. The optics and mounting are by Tinsley Laboratories.

Two different foci are provided, an f/4 Newtonian and an f/15 Cassegrainian. The Baker reflector-corrector is similar to that on the 24-inch telescope of Dyer Observatory at Vanderbilt University (Sky and Telescope, January, 1954, page 72). This accessory converts the reflector into a wide-angle Schmidt-type camera, giving excellent definition over seven-inch-square plates.

For another type of research work, the Cassegrainian photoelectric photometer, built in the physics department shop, has proven successful. Our first observations were of the three-hour variable AD Canis Minoris, in December of last year.



The new 24-inch Tinsley reflector, which has a conventional German-type mounting, is equipped with two slow-motion speeds: 60 and three seconds of arc per second of time. The primary mirror is paraboloidal and has a 96-inch focal length, giving a Newtonian focal ratio of f/4. The effective Cassegrainian focal ratio is f/15; and a skylight-shielding baffle is included. The instrument also has a Baker correcting lens, which is in position in this picture, and a 6-inch guiding telescope.

Getting Acquainted with Astronomy

The Planets — Mercury — II

Last month we discussed the movements of Mercury in the sky; now let us consider its surface features.

Telescopically, Mercury is a difficult object to study. When most conveniently placed for viewing, near the times of greatest elongation, its angular diameter is only about eight seconds of arc. Even at inferior conjunction, the disk is a scant 12 seconds across, about one-third of Jupiter's angular diameter.

The minimum equipment for observing the phases satisfactorily is probably a 3-inch telescope with a power of 100x. For more systematic observations, a 6-inch and magnifications of about 150x may be recommended.

Because Mercury is always near the horizon during twilight observations, its telescopic image is seldom steady or sharply defined. Hence, it is advantageous to view the planet by daylight, when Mercury can be seen higher in the sky, with better seeing conditions. To do this conveniently, the telescope should be equatorially mounted, preferably on a fixed pier, and have good setting circles. Predicted positions of Mercury can be found in the *American Ephemeris*.

Two precautions are important in seeking this object by day. A pure blue sky is desirable, as even a very small amount of haze is enough to wash out the contrast between the tiny disk and the surrounding sky. Also, the telescope and its finder should be carefully focused beforehand, for example on the moon, if the latter is also in the sky. If the image of Mercury is an out-of-focus blur, it is hard to pick up.

The phases of Mercury are among its most interesting phenomena for telescopic viewing. The changes are so rapid, particularly during the crescent stages, that they become appreciable in the course of a few days. The time of Mercury's *dichotomy* — when it is exactly at quarter phase — has been reported by some observers to differ by several days from predictions. Hence, it may be useful for amateur observers to determine the time of this event. A simple method is to examine the planet on successive days near greatest elongation, noting the date and hour when the terminator appears exactly straight.

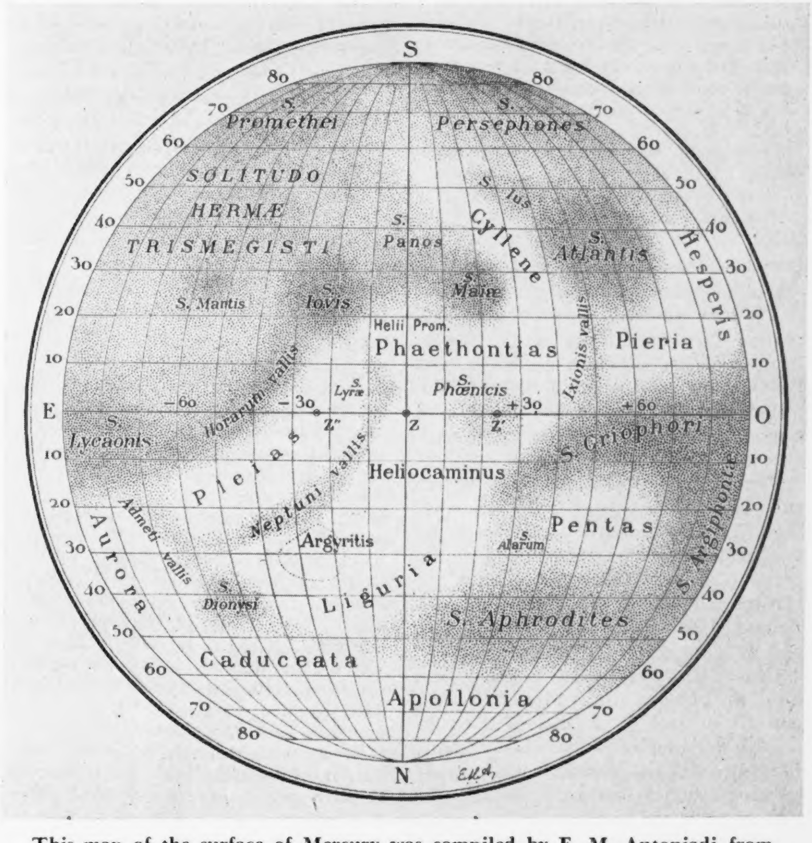
At intervals of a few years, Mercury passes directly in front of the sun at inferior conjunction, instead of north or south of it, the planet then being visible in small telescopes as a black round dot on the solar disk. The next such *transit* of Mercury will occur on November 7, 1960, and will be visible throughout North and South America. Accurate timings of the entrance of Mercury upon the sun and of its exit are useful observations for amateurs, and the phenomenon is readily photographed.

When seen under favorable conditions by an experienced eye, the reddish disk of Mercury shows dusky, streakish markings, usually near the threshold of vision. Systematic observation of these very difficult surface features is an important task for the advanced amateur. Because the markings are hard to see, they are drawn in very different fashion by various observers. But these features are permanent, and their near immobility with respect to the terminator indicates that Mercury rotates on its axis but once during each 88-day revolution around the sun.

An amateur who wishes to see something of the surface markings must prepare his eye by frequent observations of the planet. On the first observing occasion, probably nothing of the markings will be noticed; but after weeks or months of scanning the disk at all suitable opportunities, they may at last become fairly evident.

For those interested in the visual study of Mercury, one very valuable reference work is a book in French by E. M. Antoniadi, entitled *La Planète Mercure* (1934). Besides summarizing older results, it records Antoniadi's long-continued observations with the 33-inch refractor of Meudon Observatory, near Paris.

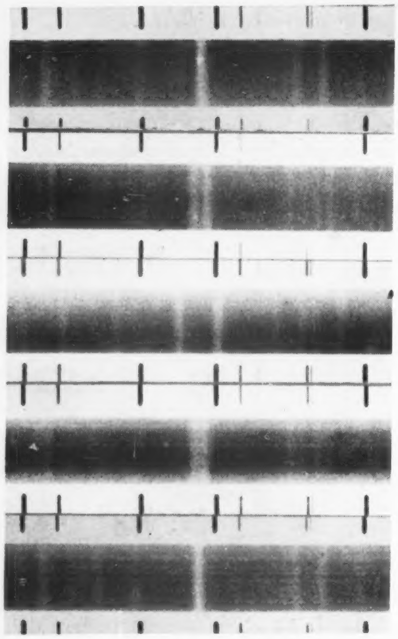
The Association of Lunar and Planetary Observers (ALPO) has a Mercury section, at present directed by Owen C. Ranck, 112 Broadway, Milton, Pa., and the work of this group is reported from time to time in the association's periodical, *The Strolling Astronomer*. Another active group is the Mercury and Venus section of the British Astronomical Association (BAA), directed by Patrick Moore, Glencathara, Worsted Lane, East Grinstead, Sussex, England. Amateurs intending to carry out systematic programs should join one or both of these groups.



This map of the surface of Mercury was compiled by E. M. Antoniadi from his observations with the 33-inch Meudon refractor about 30 years ago. The names he has given to the bright and dark regions are those in general use by students of this planet. Because Mercury rotates once for each 88-day revolution around the sun, the planet always turns the same face toward the sun, as the moon does for the earth. The libration of the planet causes the center of the apparent disk to oscillate between the positions marked Z′ and Z″. The surface markings charted here agree well with other maps from the days of G. V. Schiaparelli to the present, when allowance is made for the observing and drawing habits of different astronomers. From "La Planete Mercure."

RZ SCUTI — A Peculiar Spectroscopic Binary

OTTO STRUVE, *National Radio Astronomy Observatory**



Spectral lines of Beta Aurigae show a periodic doubling, demonstrating that this star is a binary, with a period of 3.96 days. It is also an eclipsing variable. From top to bottom, the spectrograms were taken the following number of days after mid-eclipse: 0.03, 0.21, 0.93, 1.82, and 1.94. In the middle spectrogram, where the lines are farthest apart, their spacing indicates a relative velocity of 198 kilometers per second for the two components.

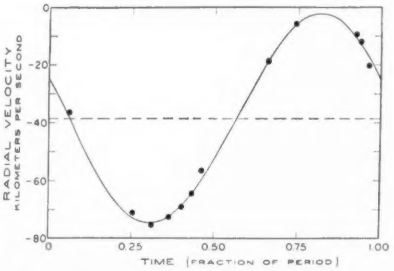
SOME of the most intriguing problems of modern astronomy are presented by the behavior of spectroscopic binaries — stars that are known to be double by the regular oscillations of their spectral lines. These wave-length shifts are Doppler displacements caused by the relative orbital motions of the stars in such binary systems.

The diagram illustrates a case of circular orbits for a pair of stars of unequal mass. The more massive star moves in the smaller orbit, always on the side of the center of gravity directly opposite the less massive component. The successive positions are labeled with the numbers 1, 2, 3, and 4.

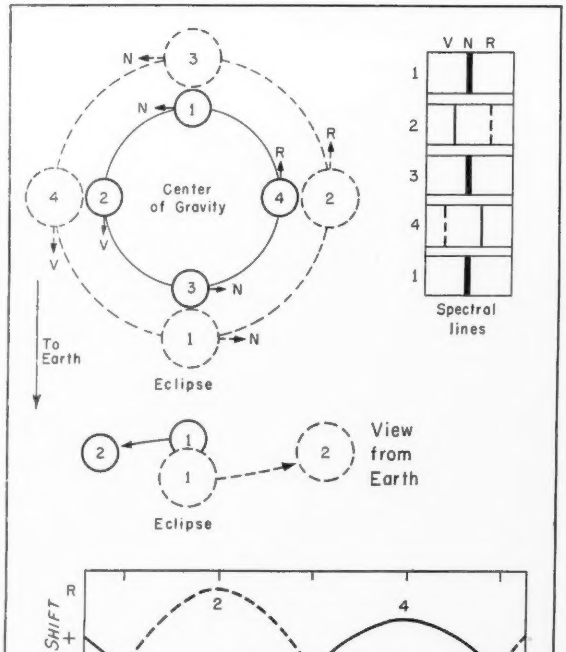
Generally, however, the orbits do not lie in the plane of the sky, but are tipped partially toward us, so that as the stars revolve one of them approaches us while the other recedes. Consider the primary star first, assuming in the diagram that the line of sight to the earth is downward. When the primary is moving sideways to this line of sight, as at 1 and 3, there is no component of its orbital motion toward or away from us, and its spectral lines are in their normal positions. But at 2 this star is approaching us, and there is a relative Doppler displacement of its lines toward the violet end of the spectrum; at 4, the recession produces a corresponding shift to the red.

If the two stars are about equal in brightness, the spectrum of the secondary can also be observed. At positions 1 and 3, however, the spectra overlap and the lines appear single for a time. But the relative motion of the secondary is always opposite to that of the primary, so near 2 and 4 of the diagram one spectrum is shifted to the violet and the other to the red, and the lines appear double. The displacement of the less massive star's lines is greater than the primary's, because the former star has the larger orbital velocity, as indicated by the arrows.

It is useful to plot the velocities of approach and recession of each component, measured from the Doppler displacements of the lines, against time or phase. This is generally expressed as the fraction of the period of revolution that has elapsed since an arbitrary zero date. The resulting velocity curve is a pair of sine waves if the stars are moving in circular orbits. In the case of RZ Scuti, the 8th-magnitude

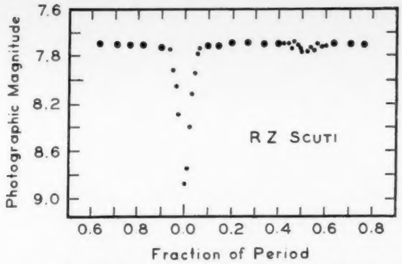


In many spectroscopic binaries, owing to the secondary star's faintness, only a single set of spectral lines appears and only one velocity curve can be drawn, as for Alpha² Herculis above.



Four aspects of a spectroscopic binary star. At the upper left are shown the orbits of the more massive component (solid circle) and the less massive one around the center of gravity. How the orbital motion affects the appearance of the spectral lines is presented at the right. When the two stars are in positions 1 or 3, their spectral lines coincide in the normal position (N), but in positions 2 and 4, lines from one star are displaced to the violet (V), lines from the other to the red (R). After frequent measurements of these Doppler shifts are made throughout an orbital cycle, the velocity curves of the two components can be plotted, as in the lowest part of this chart. If the orbit is presented edge on to the earth, or nearly so, then the secondary star at position 1 must pass in front of the other star at 1, thereby producing an eclipse.

*Operated by the Associated Universities, Inc., under contract with the National Science Foundation.



S. Gaposchkin compiled this light curve for RZ Scuti from estimates of brightness on 1,061 Harvard patrol photographs. Because the deep minimum is sharp rather than flat-bottomed, the eclipses are partial. The total duration of the eclipse is about one-sixth of the 15.19-day period.

star we shall discuss here especially, only the spectrum of the bright primary star can be observed, and the velocity curve shows the motion of this component.

Fortunately, however, the orbit of RZ Scuti is tipped so far away from the plane of the sky that its plane is near the line of sight. Each star is periodically eclipsed by the other, producing the fluctuations in total light that are characteristic of eclipsing variables. Whenever a spectroscopic binary is thus also an eclipsing system, the most interesting results are obtained from a combined study of its light and velocity curves.

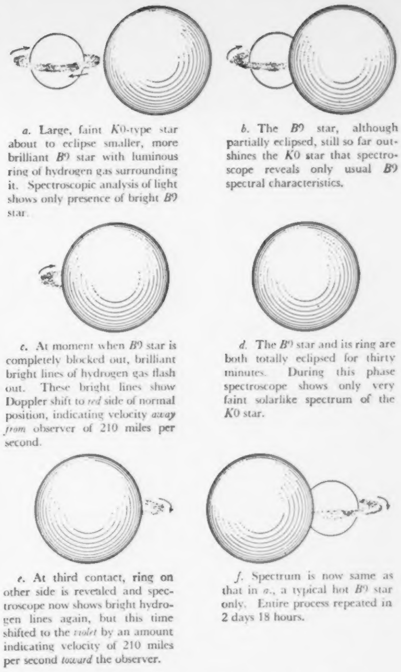
The eclipses of RZ Scuti recur in a period of 15.19 days, but no modern photoelectric light curve of this variable star seems to be in existence, and some uncertainty is attached to the photometric elements of the system, determined by H. Shapley in 1915 and S. Gaposchkin in 1943. The former gives the values 77 degrees as the inclination of the orbit to the plane of the sky, and 0.15 and 0.31 for the radii of the brighter and fainter components, respectively, in terms of the separation of their centers. It is evident that at primary minimum of the light curve a large, cool star partially eclipses a small hot one.

Two striking anomalies frequently appear in the velocity curves of eclipsing binaries. One of these is rotational distortion, which occurs during the partial phases of an eclipse, when only the edge of a bright, rapidly rotating primary is visible to one side of a larger companion. This distortion is always toward more positive values (red shifts) before mid-eclipse and toward more negative values after. Thus, the direction of rotation of the star is in the same sense as its orbital motion. There may be considerable cosmogonical significance in this universal agreement between the directions of orbital revolution and axial rotation in binary systems.

Some binaries have extremely large rotational effects in their velocity curves. An example is U Cephei, in which the eclipse is nearly central. The rotational velocity of the star being eclipsed is about 200 kilometers per second at its equator. Incidentally, in this system the spectrum of the secondary star is visible during the eclipse, when the secondary is in front of and hiding the bright primary, but outside of eclipse the light of the companion is overwhelmed by that of the brighter star.

The second anomaly, first noticed by A. H. Joy in the spectrum of RW Tauri, is found in many systems whose brighter component is a fairly hot star. Often these show double emission lines of hydrogen in their spectra. At the beginning of eclipse, the violet-displaced emission line of each pair is extinguished. During totality no emission lines are usually observed, while after totality the red-displaced emission is extinguished.

The double emission lines are believed to be produced by a gaseous ring surrounding the hot star, revolving around



a. Large, faint *K*0-type star about to eclipse smaller, more brilliant *B*9 star with luminous ring of hydrogen gas surrounding it. Spectroscopic analysis of light shows only presence of bright *B*9 star.

b. The *B*9 star, although partially eclipsed, still so far outshines the *K*0 star that spectroscope reveals only usual *B*9 spectral characteristics.

c. At moment when *B*9 star is completely blocked out, brilliant bright lines of hydrogen gas flash out. These bright lines show Doppler shift to *red* side of normal position, indicating velocity *away from* observer of 210 miles per second.

d. The *B*9 star and its ring are both totally eclipsed for thirty minutes. During this phase spectroscope shows only very faint solarlike spectrum of the *K*0 star.

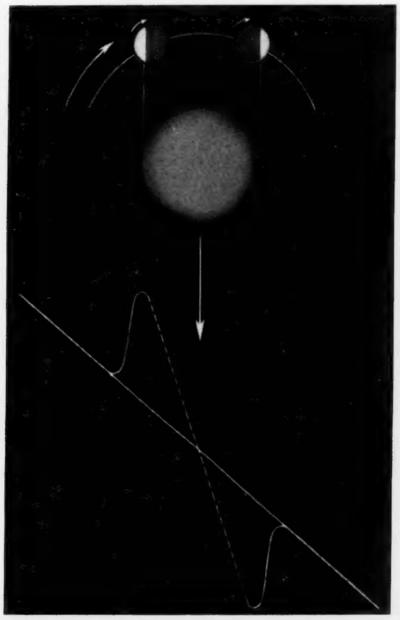
e. At third contact, ring on other side is revealed and spectroscope now shows bright hydrogen lines again, but this time shifted to the *violet* by an amount indicating velocity of 210 miles per second *toward* the observer.

f. Spectrum is now same as that in *a.*, a typical hot *B*9 star only. Entire process repeated in 2 days 18 hours.

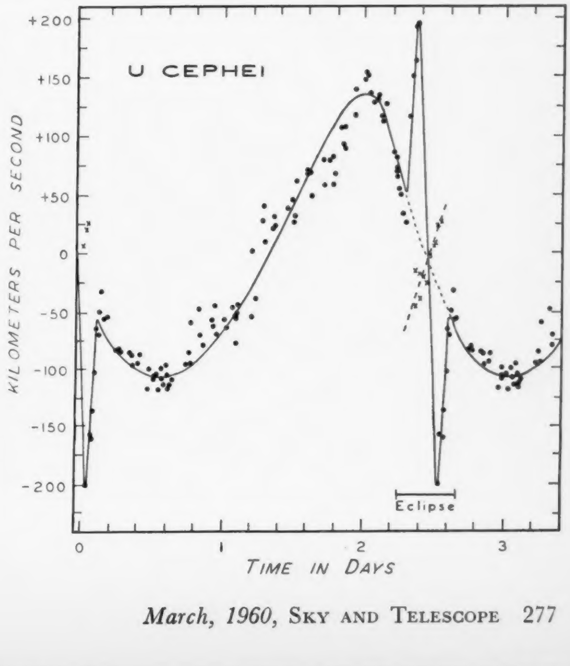
The first binary system known to contain a gaseous ring was RW Tauri, whose behavior is explained here. From Skilling and Richardson's "Astronomy," revised edition, reproduced by permission of Henry Holt and Co.

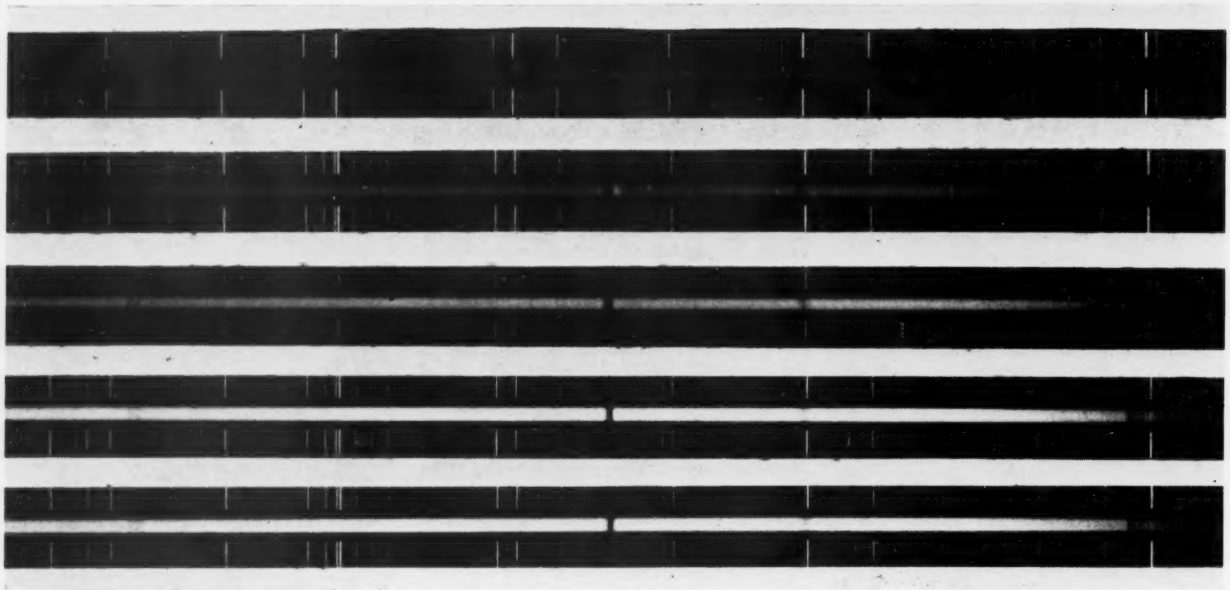
it in the same direction as its axial rotation and orbital motion. The part of the ring that is approaching us produces emission to the violet of the normal position for the star's spectral line; the other part of the ring, on the star's opposite side, is receding and produces the redward emission line. Where the ring lies between us and the star some absorption may be observable.

Confirmation of this interpretation is provided by the invisible companion as it eclipses the primary and its ring. Just as only one limb of the primary is seen at a



The rotation effect in U Cephei is illustrated by the sketch from Camille Flammarion's book "Astronomie Populaire" at the left and by the author's spectroscopic observations at the right. When the bright primary is eclipsed by the large secondary, for a short time its receding side only sends light to to the earth, and a sudden rise in the velocity curve occurs. A reverse deformation occurs after the end of total eclipse. The author has plotted with crosses the radial velocities of the secondary (whose spectrum is seen only during the eclipse).





These are parts of five spectra of RZ Scuti taken by D. H. McNamara with the 100-inch Mount Wilson telescope in June, 1957. Each stellar spectrum is flanked by two comparison spectra, added to provide a wave-length calibration. Absorption lines appear dark in this reproduction, emission features light, and shorter wave lengths are to the left. The two upper spectra were taken just after mid-eclipse, at phases 0.155 and 0.241 day, respectively. Note that the hydrogen-alpha line (prominent feature central in each picture) shows as a strong absorption, flanked by emission to the right, and weaker emission to the left. But in the third spectrum, phase 1.020 days, just out of eclipse, the leftward emission is the stronger. The two lowest spectra were obtained after eclipse, at phases 1.124 and 1.189 days, respectively. These show hydrogen alpha as an absorption feature only, this line being distinctly a close double on the original negatives. These spectrograms courtesy Dr. McNamara.

time during the partial phases of the eclipse, producing the rotational distortion, so only one side of the gaseous ring is visible, the emission from the other side being extinguished by the eclipse.

Both of these anomalous effects appear in RZ Scuti. In 1944, I made some spectroscopic observations of this star at the McDonald Observatory in Texas and obtained a good velocity curve in collaboration with the late F. Neubauer of Lick Observatory. Now K. Hansen and D. H. McNamara, Brigham Young University, have made a new spectroscopic study, which they report in the November, 1959, issue of the *Astrophysical Journal*. The new work agrees closely with the earlier results.

Hansen and McNamara use the schematic diagram to show various characteristics of the velocity curve. Two "steps," at phases nine to 12 and at 13 to 14 days, are probably produced by a ring of gas that flows around the system and may have a remarkable "eddy." Hansen and McNamara have proposed a model to explain these and other observed effects, though they point out that in all respects the model may not represent the real situation.

RZ Scuti has a very large rotational distortion, occurring between 14 and 16 days in the Hansen-McNamara diagram.

The velocity curve of RZ Scuti, determined by McNamara and K. Hansen. At the left are plotted the individual measurements of radial velocity, as given by the hydrogen lines. At the right is a schematic diagram to indicate more clearly some of the peculiar features of the velocity curve: the large rotational distortion, and the unusual steplike halts. The crosses are corrected velocities from the helium lines. Adapted from the "Astrophysical Journal."

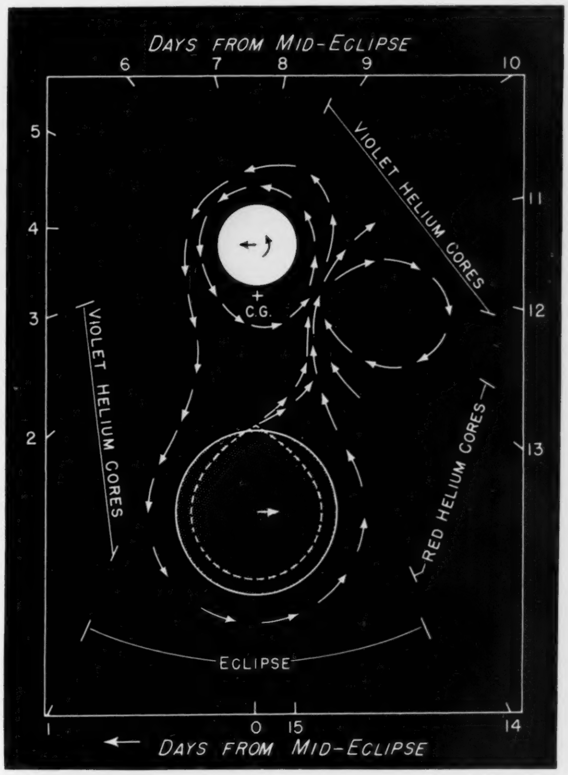
Its total observed range is some 320 kilometers per second, corresponding to a stellar rotation half as fast, or 160 kilometers per second. But the actual value must be greater than this, for two reasons. First, the orbit is tipped out of the line of sight about 13 degrees, so there is some foreshortening and thus reduction of the apparent radial velocities. Second, the eclipse is not central, and the crescents observed before and after eclipse are not centered on the star's equator but at some higher latitude where the linear value of the rotation would be less.

To check these results, Hansen and McNamara have measured the broadening of the star's helium lines outside of eclipse. In general, the faster a star rotates, the greater the differential Doppler shifts of the parts of a spectral line originating in various areas of the star's surface, some approaching us and others receding. The helium lines of RZ Scuti are broad, with measured rotation widths of about 250 kilometers per second. These values, which also must be corrected for the effects of foreshortening, confirm the very rapid rotation of RZ Scuti's primary component.

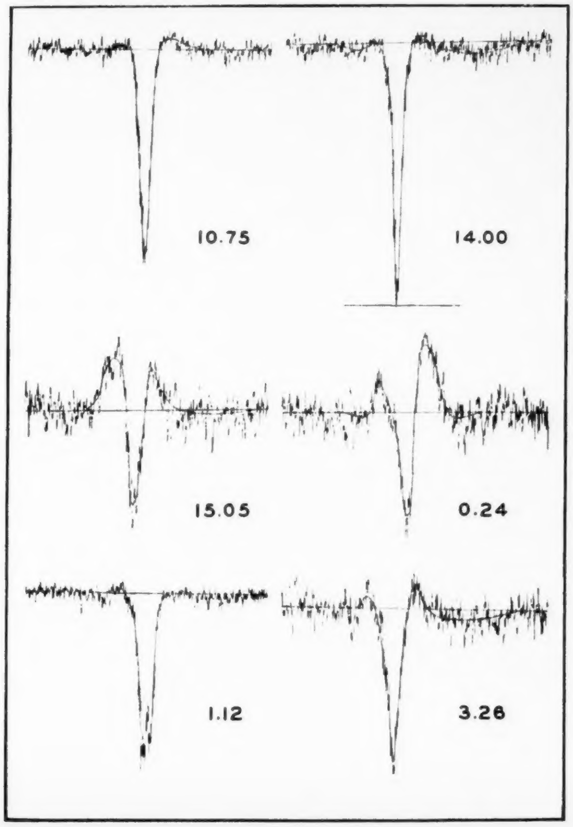
As we have seen, RZ Scuti also has double emission lines of hydrogen. The strong red hydrogen-alpha line appears both in absorption and in double emission. As with RW Tauri, the red emission is stronger than the violet one at the very beginning of partial eclipse, while the reverse is true near the very end of eclipse.

But there is a further anomaly: Just before mid-eclipse the violet component of Hα is much stronger, while just afterward the red component is the more intense. This cannot be due to a gaseous ring revolving around the primary, for that is mostly hidden behind the large secondary star. Hansen and McNamara suggest that another stream of gas flows around the secondary. Immediately before zero phase, or mid-eclipse, the *receding* part of this stream is located in front of the hot star, producing absorption but no emission. At the same time, the *approaching* part of the stream is seen projected against the dark background of the sky, thereby forming a violet-displaced emission line. As soon as mid-eclipse passes, the opposite situation occurs.

From changing asymmetries of the *helium absorption* lines of the primary star, Hansen and McNamara find a similar phenomenon, for which they believe, "The most probable explanation is that a moving gas stream surrounds the two components of the system. . . . Thus the motion of this stream must be such that before eclipse we are observing the primary component through material that is moving away from us, which causes the observed red shift of the line cores. After eclipse we are looking through material that is moving toward us, which causes the observed violet displacement of the cores." These results for the hydrogen and helium lines give a new and convincing demonstration of a stream of gas flowing around an entire stellar system.



This model of the binary RZ Scuti shows the pattern of gas streams that Hansen and McNamara believe might account for the spectroscopic peculiarities of the system. The dashed curve nearly coincident with the large star is a surface of zero velocity passing through the Lagrangian point L_1. To obtain the correct aspect of the stars and streams as seen from the earth, rotate the diagram to whatever phase is being considered. Adapted from an illustration in the "Astrophysical Journal."



The profile of the hydrogen-alpha line of RZ Scuti is shown for six different phases. Those portions of each tracing above the base line represent emission; below the base line, absorption. Compare the curves for phases 0.24 and 1.12 days with the corresponding spectra on page 278. From Hansen and McNamara, in the "Astrophysical Journal," November, 1959.

But the most interesting result, one that Neubauer and I called attention to earlier, is that the hydrogen absorption lines (and to a lesser extent the helium lines) seem to have only a small rotational distortion. In the recent work, this effect is shown to be strongly correlated with the intensities of the lines, being most noticeable for Hα.

During partial-eclipse phases, however, the absorption lines become double, and Hansen and McNamara find that the weaker component in each case *does* show the rotational distortion characteristic of

the fast rotation of the primary star's reversing layer. Thus it becomes clear that the strong component of each line, which ordinarily masks the weaker one, is produced in the revolving gaseous ring or shell. The strongest line, $H\alpha$, has the least rotational distortion and is formed highest in the shell, that is, farthest out from the star, where the shell's rotation is slowest. Other hydrogen lines are produced at lower levels in the shell, with somewhat faster rotation but still much less than that of the star itself.

The rotation of the primary is extremely rapid. If the star's orbital and rotational motions were synchronized, the equatorial velocity would be 30 instead of 250 kilometers per second. But such fast rotation is not unusual, being found in U Cephei and a considerable number of other stars.

Moreover, we can account for the relatively small rotational broadening of the shell lines. At a considerable distance above the photosphere of the hot star, the orbital velocities of the atoms in the gaseous stream would, in fact, be slower than at the photosphere itself. Furthermore, at any given phase only part of the stream is seen projected against the hot stellar disk. The resulting sharpness of the shell absorption lines can be explained in the same way as those of 48 Librae and Pleione.

An estimate of the average orbital velocity of the stream could be derived from the separation between the two emission components of $H\alpha$. Though Hansen and McNamara do not give any values, it is possible to estimate from their observations that the gaseous ring, as a whole, has an orbital velocity of about 150 to 200 kilometers per second. As the average distance of the stream from the center of the primary is roughly three times the stellar radius, the rotational broadening of the shell absorption lines would be some 50 or 60 kilometers per second. This value is in fair agreement with the appearance of the lines on spectrograms.

Because the hydrogen lines in the absorption spectrum of RZ Scuti are narrow and sharp, we would expect the bright component to have a high luminosity. But its rapid rotation indicates that it is not a supergiant and probably not even a giant. More likely it is a rather normal *B* star, perhaps on the main sequence, that owes its peculiar features not to any intrinsic properties, but to the proximity of a very large, cool giant or subgiant secondary that spills gas into the gravitational regions controlled by the hot but small primary.

We need not be too concerned over the apparent fact that the critical equipotential surface, which contains the Lagrangian point L_1 (see model diagram), is slightly smaller than the cool star. Uncertainties in the light curve, and in the corrected velocity curve, are of sufficient amount that we should really be pleased to have the secondary so completely fill its own lobe of the surface that it can expel gas through the narrow funnel at L_1 and in this way produce the streams of gas.*

Two other questions occurred to me while I was reading this *Astrophysical Journal* article. First, are there any other spectroscopic binaries whose velocity curves display the steplike appearance before the onset of partial eclipse? In the velocity curve of U Cephei (page 277), notice the striking distortion at phases 0.8 to 1.3 days, and at 1.3 to 1.8 days. No doubt the explanation in this particular case is the same as for the steps shown by RZ Scuti.

Second, is the spectrum of the hot star at mid-eclipse, when only a narrow crescent in the vicinity of its pole is visible to us, completely free of absorption produced in the gaseous stream? The spectrum of this polar area seems to be of a somewhat later spectral class than that of the entire star seen outside of eclipse (through the dense regions of the equatorial shell). Actually, though there may be some difference in the polar and equatorial spectra of the star, there is some evidence of shell absorption within this system.

My McDonald observations clearly indicated that the helium lines at these times became almost invisible, and that the hydrogen lines were weak and very narrow. This suggests that there is a small amount of hydrogen sufficiently far above and below the orbital plane to produce the narrow lines. The helium lines, being intrinsically weaker than those due to hydrogen, would be almost completely absent. Undoubtedly, the stream diffuses outward, so there is no sharp discontinuity at right angles to the orbital plane, as there is for the rings of Saturn.

*For an explanation of Lagrangian points and mass exchange in close binary systems, see my article beginning on page 70 of the December, 1957, issue of SKY AND TELESCOPE.

NEW BRIGHT VARIABLE STAR

A new 6th-magnitude eclipsing variable is reported by W. Strohmeier, Remeis Observatory, West Germany. It is HD 29365, whose 1950 position is $4^h\ 35^m.3$, $+20°\ 35'$. His study shows that the period is 2.056 days, the photographic amplitude 0.8 magnitude. The visual range could be much less, if the secondary is red.

CORRECTION TO PICTURE

Dr. James Stokley, Michigan State University, writes, "The photograph on page 151 of the January issue is one I took when visiting George W. Ritchey at the Paris Observatory in 1929. The mirror shown is about a 36-inch [not the 60-inch of Mount Wilson], and I believe he was using it in his experiments on the Ritchey-Chrétien system."

H. P. Wilkins (right) is seen with the French planetary expert Audouin Dollfus, during a recent visit of the English amateur to Meudon Observatory to work with the 33-inch telescope. Photograph by Patrick Moore.

H. P. WILKINS DIES

The world's best-known amateur observer of the moon, H. Percy Wilkins, died on January 23rd at his home in Bexleyheath, England, at the age of 62. As recently as December 31, 1959, he had retired from his position at the British ministry of supply, with the intention of devoting all his time to astronomy.

Dr. Wilkins was an active lunar observer for over 40 years. His private observatory at Bexleyheath was equipped with a 15-inch reflector, but in recent years he made many observations with the 33-inch refractor of Meudon Observatory, near Paris, in collaboration with Patrick Moore. Charting the lunar surface was his favorite work. In 1932 he published a moon map 200 inches in diameter, followed by his famous 300-inch map in 1946. Dr. Wilkins was the author of six books and numerous articles. In co-operation with Mr. Moore, he wrote *The Moon*, a 388-page descriptive survey, which appeared in 1955.

He was especially active in promoting amateur lunar observing, which had reached a low ebb about three decades ago, in his role as director of the lunar section of the British Astronomical Association, and later as president of the International Lunar Society, which he founded in 1956.

Dr. Wilkins was among the very few nonprofessional astronomers who have served as commission members of the International Astronomical Union. His honorary doctorate was given by the University of Barcelona.

In 1954, the English amateur made a lecture-tour visit to the United States, with his wife and daughter. After observing the June 30th eclipse of the sun, he attended the general convention of the Astronomical League at Madison, Wisconsin, where he received an award for his lunar work.

NEWS NOTES

RADAR ECHOES FROM THE SUN

In an epochal achievement, scientists at Stanford University Radioscience Laboratory have sent radar signals to the sun and detected the returning echoes 17 minutes later. They succeeded even though the sun's distance makes it difficult to reach by radar, and in spite of the "thunderous" radio noise arising from the turbulent solar atmosphere.

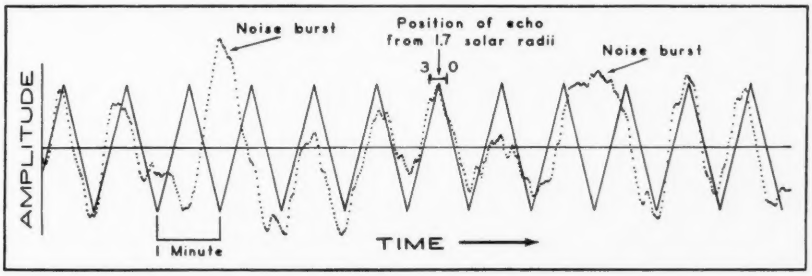
The Stanford team, headed by Von R. Eshleman and Philip B. Gallagher, used a standard transmitter, similar to those in major commercial short-wave radio stations, with an output of 40,000 watts. The antenna, used for both sending and receiving, was a four-unit rhombic array consisting of wires strung out on 22 power poles over a 14-acre area. In order to lessen the absorption of the signals by the solar corona, a frequency of 25.6 megacycles per second was chosen, which is low for radar.

Pulsed signals of 30 seconds duration, separated by an equal interval, were sent out for 15 minutes, then the transmitter was turned off while the echo was awaited. Contacts were made early on April 7, 10, and 12, 1959, but the data recorded on the magnetic tapes required elaborate analysis with electronic computers. Tens of millions of calculations were made to separate the signal echoes from the sun's background noise, which was 50,000 times stronger.

According to Dr. Eshleman, the echoes did not come from the sun's visible surface, but from the outer corona, approximately 1.7 solar radii from its center or about 300,000 miles above the photosphere. Improved techniques and more powerful transmitters may permit intensive solar exploration by radar. For instance, it is expected that much will be learned about solar flares, as well as disturbances in the corona.

The sun thus becomes the third solar system body (apart from meteors) with which radar contact has been made. Echoes from the moon were recorded as early as 1946, and from Venus in February, 1958. As in the present case, about a year elapsed from the time of the observations to the announcement of their successful analysis.

Details of the Stanford group's work have been reported in the February 5th issue of *Science*.



Here the history-making observations of solar radar echoes are presented in graphical form, as "translated" by the computer from a tape recording at the Radioscience Laboratory of Stanford University. The V-shaped straight lines show how perfect echoes would look without solar noise burst distortions or interference in the signal's path through space. Stanford University chart.

SOLAR SYSTEM SATELLITES

A comprehensive article on the satellites of the planets, containing "a more complete account . . . than is normally to be found in any single textbook," has been published in the January issue of the *Journal* of the British Astronomical Association. Written by J. G. Porter, the 27-page review contains detailed figures on each planet's system of natural satellites and a list of their discoverers.

The moon differs greatly from the other 30 solar system satellites, its orbit being everywhere concave to the sun and inclined to both the earth's equator and the ecliptic. Its mass is 1/81 that of the earth; all other satellites have far smaller masses relative to their primaries. He states, "For these and other reasons it is better to regard the Earth-Moon system as being a double planet, rejecting the old idea that the Moon once formed part of the Earth."

Dr. Porter notes the remainder are of two kinds: "regular satellites, eighteen in number, travelling in almost circular orbits in the plane of the equator of the parent planet," and "irregular satellites, which show no such behavior, but whose orbits may be quite eccentric and inclined at any angle. In this class there are twelve satellites, of which six revolve in retrograde orbits."

PERKINS 69-INCH TELESCOPE TO BE MOVED TO ARIZONA

The fifth largest reflector in the United States – the 69-inch telescope of Perkins Observatory – will be transferred from Delaware, Ohio, to Arizona late this year. The new site is on Anderson's Mesa, a flat-topped plateau about 11 miles southeast of Flagstaff, at an elevation of about 7,200 feet.

It is estimated that the 69-inch will be about four times more efficient in Arizona than in Ohio, because of the greater number of clear nights, the increased transparency, and the steadiness of the atmosphere.

Ownership of the reflector will remain with Ohio Wesleyan University, but maintenance is to be provided by Lowell Observatory. Observing time at the telescope will be divided equally between the Lowell and Perkins staffs. The astronomers from Ohio State and Ohio Wesleyan will visit the new location for three- to six-month observing periods, but the observatory in Ohio will remain the center of research in astronomy at the two universities.

In the old 69-inch dome at Delaware, a 32-inch telescope and a 16-inch Schmidt photographic camera will be set up. Grants were provided by the National Science Foundation for the large reflector's transfer and for the installation of the two new instruments.

FIREBALL OF JULY 26, 1938

A great bolide passed from over eastern Pennsylvania to southern Vermont on the early evening of July 26, 1938, attaining its greatest brilliance as it underwent several explosions north of New York City. Thousands of persons watched it flare up or burst at least four times, showering sparks as it did so. To some observers near its path, the object appeared as large as the moon.

Some 800 reports were sent in to the Hayden Planetarium, Harvard Observatory, and the American Meteor Society, together forming the largest number of reports on one fireball ever received by the society's president, Charles P. Olivier. The former director of Flower and Cook Observatory, University of Pennsylvania, has now completed his analysis of these reports, and he presents the results in the January 8th issue of *Science*.

The radiant of this meteor was in the southern constellation Centaurus. It was

IN THE CURRENT JOURNALS

THE DWARF M-TYPE STARS, by D. Nelson Limber, *Leaflet* No. 367, Astronomical Society of the Pacific, January, 1960. "It seems reasonable to conclude that in our galaxy – and possibly in the whole of the observable universe – more than half of all the stars are M dwarfs."

THE MAGNETISM OF THE SUN, by Horace W. Babcock, *Scientific American*, February, 1960. "From the variations of the magnetic fields at the surface of the sun we can deduce the patterns of fluid motions and thus perceive what lies behind the sun's ever changing visible features. In addition, magnetic studies provide clues to the nature of the turbulent activity of the sun's interior."

first observed at an elevation of 69 kilometers, descending along a gently inclined path to disappear 45 kilometers above the earth's surface. Probably it disintegrated completely in the air, so no sizable meteorites fell to the ground.

The most remarkable characteristic of the meteor, according to Dr. Olivier, was its relatively high velocity, such that before entering the earth's atmosphere it was traveling around the sun in a hyperbolic orbit, at a speed of 52.7 kilometers per second. This would imply that the object was not a member of the solar system, but an interloper from outside. For no previous case has this been established to the general satisfaction of meteor astronomers.

However, the deduced velocity depends critically upon the observed duration. The 1938 fireball was not photographed with meteor cameras, and the 183 visual estimates of duration show a considerable spread. After discarding all those under 4.0 seconds as too short, and six over 43 seconds as much too long, Dr. Olivier obtained 9.71 seconds as the average of the remaining 145 estimates. Thirty-three of these were within one second of the average.

RANGE OF RADIO TELESCOPES

At Sugar Grove, West Virginia, the U. S. Navy is building the world's largest steerable radio telescope, having a paraboloidal antenna 600 feet in diameter, with a surface area of more than seven acres. In an article describing this project (*Scientific American,* January, 1960), Naval Research Laboratory astronomer Edward F. McClain points out the fallacy in the popular belief that this instrument will be able to "see" 40 billion light-years into the universe. He writes:

"In a static universe it could detect a bright radio object such as a pair of colliding galaxies at that great distance. But in our expanding universe the limit of radio observations is in practice the same as the limit of observation in the visible spectrum — far short of 40 billion light-years. It is the red-shift that sets the outer boundary on the reach of both kinds of telescopes."

XENON IN METEORITES

A meteorite that fell in Richardton, North Dakota, 41 years ago contains a vital clue concerning the origin of the solar system. From analysis of a minute trace of the rare gas xenon trapped in the meteorite, John H. Reynolds, University of California physicist, concludes that the chemical elements out of which the planetary system was formed had finished evolving almost five billion years ago.

The crucial observations were made with an extremely sensitive mass spectrometer, which can measure the abundances of isotopes in a very small sample. Although the meteorite was only six trillionths xenon by weight, the University of California's instrument permitted detailed studies of xenon isotopes from but a few grams of meteoritic material.

Xenon from the meteorite contains relatively more of the isotope having atomic weight 129 than any sample of the element previously studied. According to Dr. Reynolds, the only possible source of most of the Xe^{129} is radioactive decay of the iodine isotope of the same atomic weight, I^{129}, which no longer exists on the earth.

After the formation of the elements in the solar system, half of the available I^{129} decayed into Xe^{129} every 17 million years, so this isotope of iodine disappeared early in the solar system's history. However, the meteorite was evidently created soon enough after the elements were formed to contain traces of I^{129}. Detailed calculations fix this time at 350 million years. Since this type of meteorite is generally considered to be 4,600 million years old, an age of 4,950 million years is inferred for the elements as a whole.

OPTICAL TESTING ON STARS

A simple, widely used method of testing a telescope is to compare the appearance of a star image just inside and outside of focus. If optical aberrations are absent, images that are equidistant from the plane of best focus should be identical in appearance, provided the light rays entering the instrument are parallel.

W. T. Welford, Imperial College, London, has investigated theoretically the limiting sensitivity of this test. His calculations show that, under *ideal* conditions, sharp localized errors as small as 1/60 wave length of light might be recognized, or errors of 1/20 wave length if they vary gradually over the optical surface. In comparison, the Foucault knife-edge test has a limiting sensitivity in visual tests of about 1/20 wave.

Mr. Welford points out that the highest precision can be approached only by a very experienced optical worker, using an artificial starlike light source under laboratory conditions. If an actual star is used as the test object, the procedure's sensitivity is adversely affected by imperfect atmospheric seeing conditions.

This study was published in the *Journal* of the Optical Society of America for January.

NEW HARVARD-SMITHSONIAN RESEARCH BUILDING

A four-story workshop for astronomers, containing 40,000 square feet of offices and laboratories, is being erected at Harvard Observatory in Cambridge, Massachusetts. Located just to the east of the 15-inch refractor's dome, the F-shaped structure is scheduled for completion in about a year.

The new quarters are to be used by both Harvard and Smithsonian Astrophysical Observatory astronomers, and will enable the latter institution to bring together its research groups now scattered elsewhere in the city. The building will contain a high-speed IBM computer for use in tracking artificial satellites, a principal activity of Smithsonian astronomers.

TYCHO BRAHE'S THEORY OF THE SOLAR SYSTEM

Many textbooks contain reproductions of the diagram Tycho Brahe published in 1588 to illustrate his plan of the arrangement of the solar system. He proposed that only the moon and sun revolved about the stationary earth, while the other planets and comets had orbits around the sun. Thus, Tycho's theory was a compromise between the ancient idea of an immovable earth and the sun-centered arrangement proposed by Copernicus.

Until recently, the original Latin text of Tycho's description of his theory had not been published in an English version. This has now been done at the University of California by Marie Boas and A. Rupert Hall, whose translation appears in *Occasional Notes* of the Royal Astronomical Society (Vol. 3, No. 21, November, 1959). They present the pertinent portion of his long treatise on the comet of 1577.

Tycho's model eased the way for the gradual acceptance of Copernicanism. The Danish astronomer demolished the traditional belief that the planets were carried along by actual spheres of hard and impervious material. Comet motions indicated to him that the solar system bodies were moving freely through space, in obedience to natural law, and he even suggested that the path of the comet of 1577 might not be "at all points exquisitely circular, but somewhat oblong, in the manner of the figure commonly called ovoid." Tycho's assistant, Johannes Kepler, later applied the idea of elliptical orbits to the entire family of planets.

TEXAS SUMMER WORKSHOP FOR HIGH SCHOOL STUDENTS

Sponsored by the National Science Foundation, a summer institute in astronomy and allied sciences for secondary school students will be offered from June 6th to July 15th by the Pan American College, in Edinburg, Texas. Selection of participants will be made according to academic records and appropriate tests. Information may be obtained by writing to Observatory and Astro-Science Center, Pan American College, Edinburg, Tex., or to the Texas Education Agency, Austin, Tex.

OHIO APPOINTMENT

Arne E. Slettebak has been named director of Perkins Observatory, which is operated jointly by Ohio State and Ohio Wesleyan universities. He was advanced from assistant professor to professor at both institutions. Dr. Slettebak is also director of OSU's McMillin Observatory.

OBSERVING THE SATELLITES

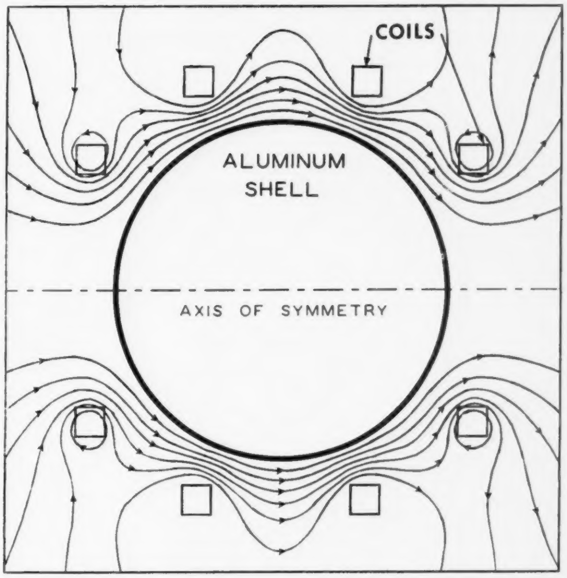
Astronomical Observing from Above the Earth's Atmosphere

ROCKET-BORNE instruments have already given us a foretaste of the rewarding observations of the sun and other celestial bodies that can be made in far-ultraviolet light. The earth's atmosphere is opaque to this region of the spectrum, forcing us to observe from rockets that can reach extremely high altitudes or from artificial satellites.

However, during the brief flight of a rocket, only a few minutes of astronomical observation are possible. There would be much advantage, therefore, in placing a telescope in an artificial satellite that would remain aloft for months or years. Recent planning for such satellite instruments was described last December at Cleveland, Ohio, in a symposium sponsored by the American Astronomical Society and the National Science Foundation.

Lyman Spitzer, Jr., Princeton University Observatory, told of a novel system for stabilizing a satellite carrying a 24-inch reflecting telescope, to permit exposing high-dispersion spectrograms for as long as 12 hours, with a guiding accuracy of 0.1 second of arc. He discussed the problems of guidance, pointing, temperature control, and reliability of operation.

This inertial sphere is proposed by Princeton University astronomers to stabilize an artificial satellite carrying a space telescope. Through varying the magnetic field produced by the coils around the aluminum sphere, the latter's rotation can be changed, thereby taking unwanted angular momentum from the satellite. The magnetic field strength is inversely proportional to the separation between the lines of force and to distance from the axis of symmetry. Princeton Observatory diagram.



Guidance and pointing are closely related. In the first, the stability of the satellite must be maintained against the action of disturbing forces. In the second, a torque must be applied to the telescope to set it on another part of the sky, yet the reaction to this motion must not cause the satellite to rotate.

Radiation pressure of sunlight, which might amount to three or four dynes of force on a two-meter cube, and the approximately equal pressure due to atmospheric drag at an orbital height of about 500 miles, would both be dealt with by having the center of gravity of the satellite very close to its geometrical center.

The one-ton vehicle contemplated by Dr. Spitzer would contain 22 pounds of iron, which would have to be demagnetized to minimize torque caused by the earth's magnetic field. Furthermore, inhomogeneities in the earth's gravitational field can produce tidal torque. This can be greatly reduced by making the satellite's three principal moments of inertia equal to within one part in 1,000.

Pointing or setting of the telescope will probably have to be done rather rapidly, during up to 10 minutes of radio contact with a ground control station. For a 180-degree turn of the telescope, a setting time of five minutes might require a torque of 10^5 dynes per centimeter, and this must be counterbalanced by an active mechanism.

Gas jets, which have been used to stabilize some previous artificial satellites, cannot serve for the Spitzer vehicle, because its orientation must be controlled for a year; the weight of gas to be carried would be prohibitive. Hence, for both pointing and stabilization, angular momentum must be transferred *inside* the satellite.

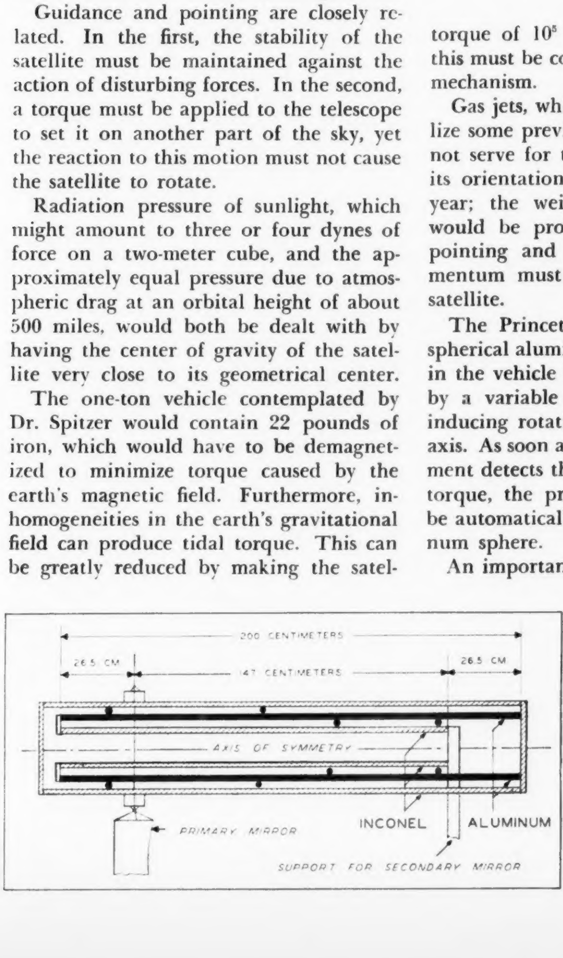
The Princeton astronomer proposes a spherical aluminum shell, suspended within the vehicle in a state of weightlessness by a variable magnetic field, the latter inducing rotation of the shell about any axis. As soon as the optical guiding equipment detects the need for a compensating torque, the proper amount of spin will be automatically transferred to the aluminum sphere.

An important advantage of this scheme is that the shell's spin would not increase indefinitely. Eddy currents induced in the rotating sphere by the earth's magnetic field would damp the rotation. However, at heights much above 500 miles the terrestrial field is too weak to be effective.

A major problem in operating the telescope will be getting the proper star on the spectrograph slit, especially if the star is faint. Three methods have been suggested. One is to use a television system of the type that has worked so well in Project Stratoscope, for solar photography from an unmanned balloon. Another is to have a second telescope that will track a neighboring 1st-magnitude star. The third procedure would be to set on a bright star and then move by differential corrections to the position of the faint one to be observed.

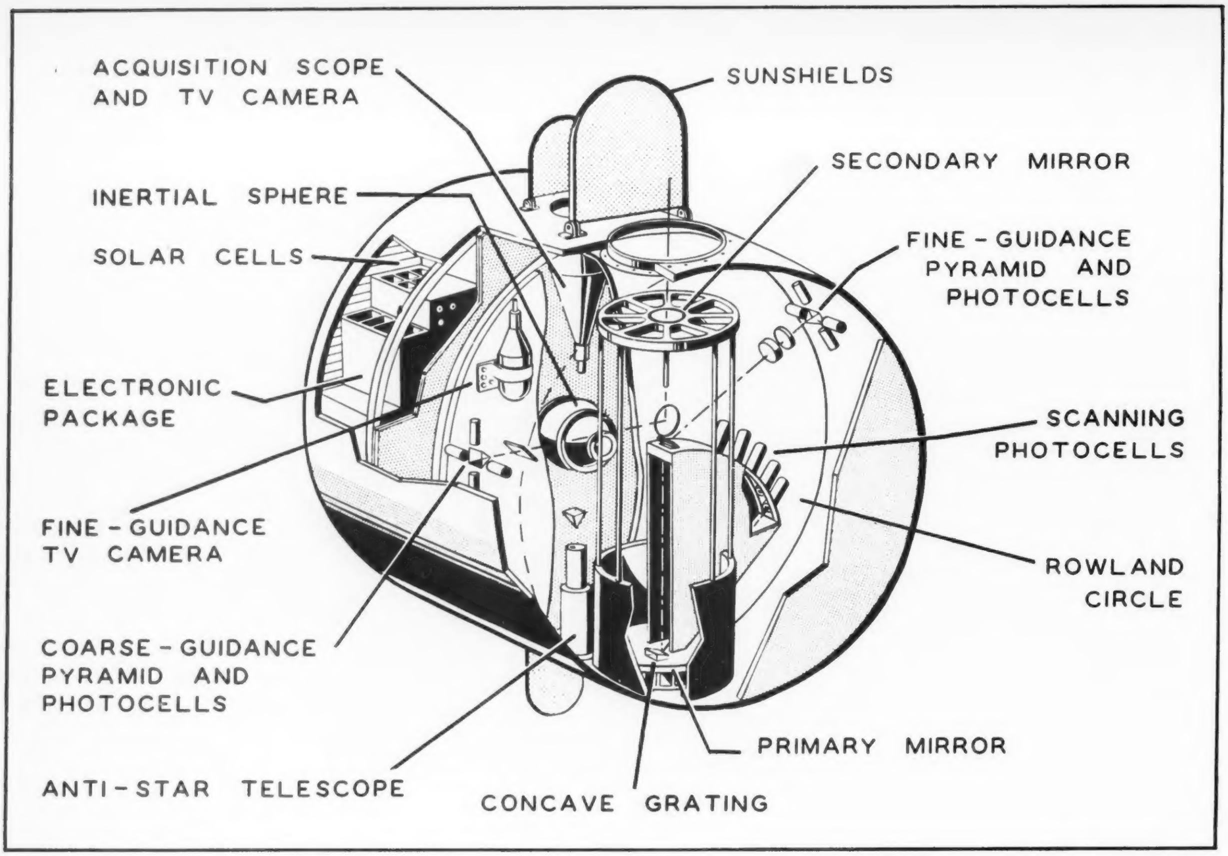
As seen from the satellite, the star might temporarily be occulted by the earth. In order to relocate it after it once more becomes visible, an anti-star telescope is proposed, pointing to some other star in the opposite part of the sky.

Temperature requirements will be severe. The phototubes for the guiding and sensing systems operate best in cool surroundings, while batteries require warmth. As the sketch of the satellite on page 284 shows, it would be divided into two sections, one containing the batteries and electronic package and always turned toward the sun; the other, containing the telescope, guidance system, and inertial sphere, would be kept cool by being turned away from direct sunlight. The two compartments are to be separated by a wall of heavy insulation.



Expected temperature changes will not alter the dimensions of the space telescope by one part in a million, thanks to this arrangement of aluminum and inconel tubes, devised by John B. Rogerson, Jr.

With this arrangement, the temperature inside the telescope compartment could still vary by about 15 degrees centigrade, because of radiation received from the earth. The optical system must be constructed so that it will be unaffected by such thermal changes. John B. Roger-



The Spitzer space-telescope satellite. Princeton Observatory diagram.

son, Jr., of Princeton, proposes that the primary and secondary mirrors of the 24-inch Cassegrainian be held together by a combination of inconel and aluminum tubes, with separate inner and outer frames. The principle involved is the same as in the pendulum of a temperature-compensated clock. With Dr. Rogerson's design, the separation between the two mirrors should remain constant to one part in a million over the expected temperature range — from 178° to 208° Kelvin.

Dr. Spitzer plans to use the 24-inch telescope solely for ultraviolet spectroscopy, in the wave-length region from 800 to 3200 angstroms. The spectrum will be "read" by pulse-counting photocells, whose data will be stored on tape for later transmission to Earth. The hot star Zeta Persei is one of the first choices on the astronomer's observing list.

In the prototype space telescope that is depicted here, the axis of the cylindrical housing is perpendicular to the 24-inch telescope's optical axis. The smaller sunshield will prevent sunlight from falling on the finder or acquisition telescope, which has a 10-degree field of view. The larger shield is to keep stray light from entering the main instrument. There is a third screen for the anti-star telescope, which is located on the side of the cylinder opposite the finder.

The main path of light is past the secondary mirror downward to the primary, from which it is reflected back to the secondary and thence to the slit of the spectrograph. The small concave grating just in front of the primary produces a spectrum along the Rowland circle, where the intensity at various wave lengths will be measured by the five pulse-counting photocells. Although the spectrograph slit will be very wide, it is hoped that the resolution will be 0.1 angstrom per millimeter.

A small diagonal mirror below the secondary will reflect some light to the coarse-guidance photocells, and part of this beam is to be deflected upward to the fine-guidance television camera, which has a field of half a degree. The jaws of the spectrograph itself will deflect some light toward the fine-guidance photocells at the upper right.

Successful operation of this satellite will require thousands of individual mechanical and electronic parts that must function properly for long periods. Studies of component reliabilities indicate that electric motors may typically fail at a rate of about 20 per cent per year, vacuum tubes at about 10 per cent, and various other elements also have a finite probability of failure. Hence, Dr. Spitzer pointed to the need for standby units to be built into the vehicle.

Rocket boosters for the ambitious Princeton program will not be available for a few years. Meanwhile, late this year or early in 1961, an ultraviolet study of part of the sky may be made from an Aerobee rocket, in a program outlined by Fred L. Whipple, Smithsonian Astrophysical Observatory. A 3-inch f/4 mirror will be used in conjunction with standard television equipment, the image tube being covered by a multicolor mosaic filter.

At the height of the rocket's flight, about five minutes will be available for taking photographs, probably at the rate of 30 frames per second. The spectral region from a little below Lyman-alpha to about 2000 angstroms would be covered, and the light from nebulosities and bright stars in a strip four degrees wide and 150 degrees long would be recorded, possibly beginning near Orion. The eventual aim of this program includes a broad survey of the entire sky in four colors between 1000 and 3000 angstroms.

MARSHALL MELIN
Research Station for Satellite Observation
P. O. Box 4, Cambridge 38, Mass.

CORRECTION

In the right-hand diagram on page 91 of the December, 1959, issue, the arrowheads showing the direction of the moon's motion were reversed by a drafting error.

AMERICAN ASTRONOMERS REPORT

Here are highlights of some papers presented at the 104th meeting of the American Astronomical Society at Cleveland, Ohio, December 27-30, 1959. Complete abstracts will appear in the Astronomical Journal.

Gas Motions in the Central Part of M31

At Palomar Observatory, Guido Münch has used the 200-inch reflector to study the spectra of gaseous nebulae close to the nucleus of the great Andromeda galaxy. Among the most prominent spectral features of emission nebulae are bright lines at 3726 and 3728 angstroms, due to singly ionized oxygen. With a prime-focus spectrograph giving a dispersion of 66 angstroms per millimeter, Dr. Münch could observe these oxygen lines out to a distance of 50 seconds of arc from the center of M31.

Since the Andromeda galaxy is rotating, the nebulosities in one half of it should be approaching us, those in the other half receding. But the radial velocities found by Dr. Münch show large departures from the rotational pattern. The gas seems to have a well-defined outward motion, amounting to 50 kilometers per second at a distance of 200 parsecs from the nucleus.

The California astronomer made his observations with the spectrograph slit placed in various orientations. The noncircular nature of the motion was most prominent when the slit was placed along the minor axis of the spiral galaxy, a position in which rotational effects should vanish, since rotation would be at right angles to the line of sight. He suggests that the observed expansion is taking place predominantly in the central plane of M31.

A similar expansion of gas near the center of the Milky Way galaxy has been found by Dutch radio astronomers, from measurements of the 21-centimeter line of interstellar hydrogen (SKY AND TELESCOPE, May, 1959, page 368).

Spectral Surveys Including the Ultraviolet

In a joint project, astronomers at Hamburg Observatory in West Germany and at Warner and Swasey Observatory in Ohio are surveying the northern sky, in order to find stars of high intrinsic luminosity. Already the two institutions have obtained objective-prism plates of nearly all Milky Way regions from Scutum through Cygnus to Perseus.

The Ohio observers use on their 24-inch Schmidt telescope an objective prism that allows stellar spectra to be recorded to wave lengths as short as 3200 angstroms in the ultraviolet. Hitherto, most spectral classification has been done at considerably longer wave lengths. The new prism (see page 317 of the April, 1959, issue) gives a scale of 580 angstroms per millimeter at the blue hydrogen-gamma line.

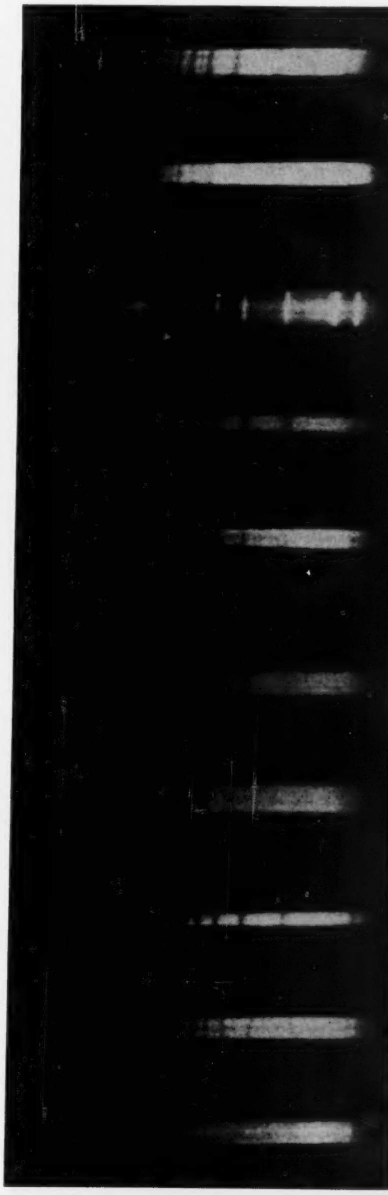
Previously, A. Slettebak and J. Stock had published criteria for classifying different types of stars, derived from objective-prism spectra utilizing the ultraviolet region and particularly the Balmer discontinuity. In the current similar work, Case Institute astronomers J. J. Nassau and C. B. Stephenson have obtained results for the *OB* stars and the other highly luminous classes that are in general good agreement with the earlier investigation. They report that they can pick out supergiant stars (of luminosity classes Ia, Ib, and II) between *B*7 and *G*0, and giant stars (III) from *B*7 to *A*5 and also at *G*0.

Several varieties of abnormal spectra can be studied advantageously on the Warner and Swasey photographs. For example, white dwarf stars of type *A* are recognizable by their broad hydrogen lines, and by the strong ultraviolet extension of their continuous spectra. At least some *A* subdwarfs are identifiable by the absence of a drop in spectral intensity just to the violet of the head of the Balmer series, if at the same time the hydrogen lines are weak to a degree indicating a high-luminosity star.

Drs. Nassau and Stephenson call attention to peculiarities in the ultraviolet spectra of two variable stars, also pictured here. RR Lyrae shows the earmarks of a higher luminosity than astronomers generally assign to variables of this variety. The novalike star Z Andromedae presents a noteworthy feature: the strong continuous emission due to hydrogen, at the ultraviolet side of the Balmer head.

While the inclusion of the ultraviolet region is useful in detecting certain variables, for example the R Coronae Borealis and SS Cygni types at minimum light, some other kinds of peculiar stars appear normal at the low dispersion used. Moreover, *F* subdwarfs escape detection.

The Milky Way survey includes red plates, in the wave-length region 5900-7000 angstroms, to eliminate early-type hydrogen-emission objects that simulate highly luminous *OB* stars. These plates also prove useful in the identification of planetary nebulae, emission-line stars, carbon stars, and early *M* and *S* stars, all with greater certainty than in previous infrared surveys.



These samples of objective-prism spectra include the ultraviolet region to about 3200 angstroms, and were taken with the Schmidt telescope of Warner and Swasey Observatory. From top to bottom they are: 1, an A5 giant; 2, RR Lyrae; 3, Z Andromedae; 4, a white dwarf; 5, an A2 subdwarf; 6, an F2 main-sequence star; 7, an F2 supergiant; 8, an A2 main-sequence star; 9, an A2 supergiant; and 10, a highly luminous OB star. Notice the variations in line widths as well as in ultraviolet extensions among stars of different intrinsic luminosities. Case Institute of Technology photograph.

Diameters of Lunar Craters

The number of lunar craters increases rapidly with decreasing size, and it has been estimated that there are about 300,000 of them larger than one kilometer in diameter on the visible hemisphere of the moon. Some important con-

clusions have been drawn by E. J. Opik, now at the University of Maryland, from the relative numbers of craters of different dimensions.

He selected an area of 465,000 square kilometers in the western part of Mare Imbrium, and measured the rim-to-rim diameters of 812 craters within it, using an enlarged print of a photograph taken in 1919 with the 100-inch Mount Wilson reflector. While some craterlets as small as 0.6 kilometer across could be measured, Dr. Opik believes his listing includes all objects larger than 1.2 kilometers, numbering 733. He found 208 larger than 2.5 kilometers, 35 of more than 5.4, and 10 of more than 13 kilometers.

If these craters were formed by meteoric masses striking the moon's surface with velocities of 20 kilometers per second, the projectiles would have had diameters about 1/20 of those of the cavities they produced. On this basis, Dr. Opik could compute how many craters of each size would have been formed in the 4.5 billion years that the solar system has presumably existed.

The agreement between the observed and predicted counts is excellent, except the few craters much larger than 13 kilometers in diameter are less rare than expected. Dr. Opik therefore concludes that the frequency of meteoritic bodies in space, at the earth's distance from the sun, has not varied greatly since the mare was formed. Furthermore, the age of the latter seems comparable with that of the solar system.

Are Stars Alike in Different Parts of the Universe?

In studies of star formation and of the evolution of galaxies, the following problem is basic. Suppose a quantity of primitive material is converted into stars. The distribution of intrinsic brightnesses among these newly formed stars is called the *initial luminosity function*. It tells the relative numbers of stars for each absolute magnitude, before the stars have evolved appreciably. For different stellar samples, formed from the same amount of matter, but at different times and places in the universe, will this function be the same?

Recently a number of astronomers have assumed that such a uniformity in fact exists. D. N. Limber, of Yerkes Observatory, has now tested whether this assumption is consistent with observation, and finds strong evidence against it.

The first step in his investigation was to derive the initial luminosity function for well-observed stars in the solar neighborhood and in galactic clusters. Then, making use of the modern theory of stellar evolution, he could predict how the mass-to-light ratio of this sample of stars would change as the stars aged.

Next, he compared this changing mass-to-light ratio with the observationally determined values of the ratio for globular clusters and for other galaxies than ours. This comparison led to two alternatives: Either the initial luminosity function does differ among stellar systems, or a significant fraction of the stellar systems in the observable universe is well over 20 billion years old. An age so great is unlikely, according to Dr. Limber, who prefers the first alternative.

He concludes, "It thus appears that the form of the initial luminosity function depends in a marked way upon at least certain of the parameters that describe the prestellar medium from which stars form —parameters such as density, temperature, turbulent velocity, magnetic field strength, and chemical composition."

Older Meteor Streams

A new class of meteor stream that produces long-lasting, sparse showers has been revealed by an analysis of photographs obtained with Baker super-Schmidt cameras in New Mexico. The study was reported by G. S. Hawkins and R. B. Southworth, Harvard Observatory.

They first established a criterion by which to distinguish members of a stream from nonmembers. This criterion, D, specifies the difference between the orbits of any pair of meteors. Calculated from their orbital elements, D approximately equals the velocity change that would convert one orbit into the other. Hence, the smaller the value of D for a pair of meteors, the greater is the likelihood that they are related.

For known meteor streams, the differences between the mean orbit and orbits of the member particles gave an average value of 0.09 for D, with more than 90 per cent of the values being 0.20 or less.

Next, all pairs of orbits for which D was not over 0.20 were selected from a random set of 360 meteors photographed in New Mexico. Some 13 per cent of this group had previously been known to belong to streams with more than three meteors per hour, as counted by a single observer. But about 40 per cent more were found to be associated, forming 32 minor streams, only six of which had previously been recognized among photographic meteors. A control experiment, seeking similar groupings among random artificial meteors, showed 57 per cent of the minor streams to be genuine.

Meteor showers of the newly recognized class are characterized by very broad radiant areas and the appearance in one observer's sky of less than one meteor per hour. The Harvard astronomers believe that the particles involved in these streams have been more affected by perturbations than those in the major streams, but have not yet been wholly dispersed into sporadic orbits.

Two of the principals at the 104th meeting of the American Astronomical Society were, left, Fred Hoyle, St. John's College, Cambridge University, who served as chairman of the symposium on astronomical observations from above the earth's atmosphere, and J. J. Nassau, Case Institute of Technology. Photograph by James Breckinridge.

QUESTIONS... FROM THE S+T MAILBAG

Q. What is meant by the term globule?

A. Photographs of certain bright nebulae (page 156, January issue) show small dark markings, more or less circular. These globules are compact dust clouds, with diameters between 10,000 and 100,000 astronomical units, which many astronomers believe represent an early stage in the formation of stars.

Q. What are some good double stars for a beginner with a 1.6-inch telescope?

A. Five beautiful yet easy pairs are Alpha Canum Venaticorum, Beta Cygni, Nu Draconis, Zeta Ursae Majoris, and Gamma Virginis. Two other pairs so wide as to be easily split in binoculars should be examined: Alpha Capricorni and Epsilon Lyrae.

Q. In referring to a double star, what do *preceding* and *following* mean?

A. The preceding component of the pair is the more westerly, for as the earth's rotation causes the stars to drift across the field of a stationary telescope it will lead the other component, the following one.

Q. What is the range of light variation of Polaris?

A. Polaris is a Cepheid variable star which changes by 0.09 magnitude visually, in a period of 3.97 days. In blue light the range is 0.14 magnitude.

Q. Which of the known asteroids can come closest to the sun?

A. The minor planet 1566 Icarus, discovered in 1949, passes inside the orbit of Mercury. When farthest from the sun, it is outside the orbit of Mars. W. E. S.

Amateur Astronomers

CONTACTING NATIONAL ORGANIZATIONS

Many amateurs are interested in affiliating with a national organization. Information may be obtained from the officers listed here.

American Association of Variable Star Observers. Mrs. Margaret W. Mayall, Director, AAVSO, 4 Brattle St., Cambridge 38, Mass.

American Meteor Society. Dr. Charles P. Olivier, President, AMS, 521 N. Wynnewood Ave., Narberth, Pa.

Association of Lunar and Planetary Observers. Walter H. Haas, Director, ALPO, Pan American College Observatory, Edinburg, Tex.

Astronomical League. Mrs. Wilma A. Cherup, Executive Secretary, AL, 4 Klopfer St., Pittsburgh 9, Pa.

Western Amateur Astronomers. Walter J. Krumm, Chairman, WAA, 10628 Larry Way, Cupertino, Calif.

OMAHA, NEBRASKA

At two successive hobby exhibitions, the Omaha Astronomy Club's planetarium has been an exceptionally popular attraction. The projector was constructed by David Solzman, our immediate past president, and the dome was made by club members under the direction of Leo Baum.

By arrangement with the Northern Natural Gas Co., which owns the former American Legion building, the planetarium will shortly be installed there permanently. Our society is also to have a meeting room and optical workshop.

We now have 80 members and 15 telescopes. Monthly public star parties usually bring out from seven to 10 instruments and from 300 to 500 persons. Presently we meet on the second and fourth Sundays of the month in the Joslyn Memorial Museum at 2:30 p.m.

ALEXANDER McDONOUGH
710 N. 58th St.
Omaha 32, Neb.

GEORGIA AMATEUR DIES

Patrick O. Parker, secretary of the Southeast Region of the Astronomical League, passed away January 8th at Atlanta, Georgia. The 73-year-old amateur was a member of the Atlanta Astronomy Club and the American Association of Variable Star Observers.

YUCAIPA, CALIFORNIA

A new group in southern California is the 10-member Yucaipa Amateur Astronomers. The secretary is Charles M. Tapley, 33089 Yucaipa Blvd., Yucaipa, Calif.

THIS MONTH'S PROGRAMS

Baltimore, Md.: Baltimore Astronomical Society, 8 p.m., Central Pratt Library. March 21, Mrs. Grace Scholz Spitz, "The New Role of Astronomy in Science and Industry."

Cleveland, Ohio: Cleveland Astronomical Society, 8 p.m., Warner and Swasey Observatory. March 11, Dr. K. A. Strand, U. S. Naval Observatory, "Star Clusters."

Dallas, Tex.: Texas Astronomical Society, 8 p.m., Health and Science Museum Planetarium. March 28, Charles S. Frazier, "Outline of Summer Observing Program."

New York, N. Y.: Amateur Astronomers Association, 8 p.m., American Museum of Natural History. March 2, Dr. Arthur Beiser, New York University, "The Earth's Magnetic Personality."

New York, N. Y.: Junior Astronomy Club, 8 p.m., Waverly building, New York University. March 18, Mrs. Margaret W. Mayall, American Association of Variable Star Observers, "Observing Variable Stars."

Philadelphia, Pa.: Rittenhouse Astronomical Society, 8 p.m., Franklin Institute. March 11, Dr. Raynor L. Duncombe, U. S. Naval Observatory, "Modern Navigation Methods."

Pittsburgh, Pa.: Amateur Astronomers Association of Pittsburgh, 8:15 p.m., Buhl Planetarium. March 11, J. Mullaney and G. Doschek, "Lunar and Planetary Research."

Syracuse, N. Y.: Syracuse Astronomical Society, 8 p.m., Steele Hall, Syracuse University. March 24, motion picture, How Many Stars?

Washington, D. C.: National Capital Astronomers, 8:15 p.m., Commerce Department auditorium. March 5, Dr. R. Glenn Hall, U. S. Naval Observatory, "The Determination of Time."

A NEBRASKA PLANETARIUM WITH AN UNUSUAL ENTRANCE

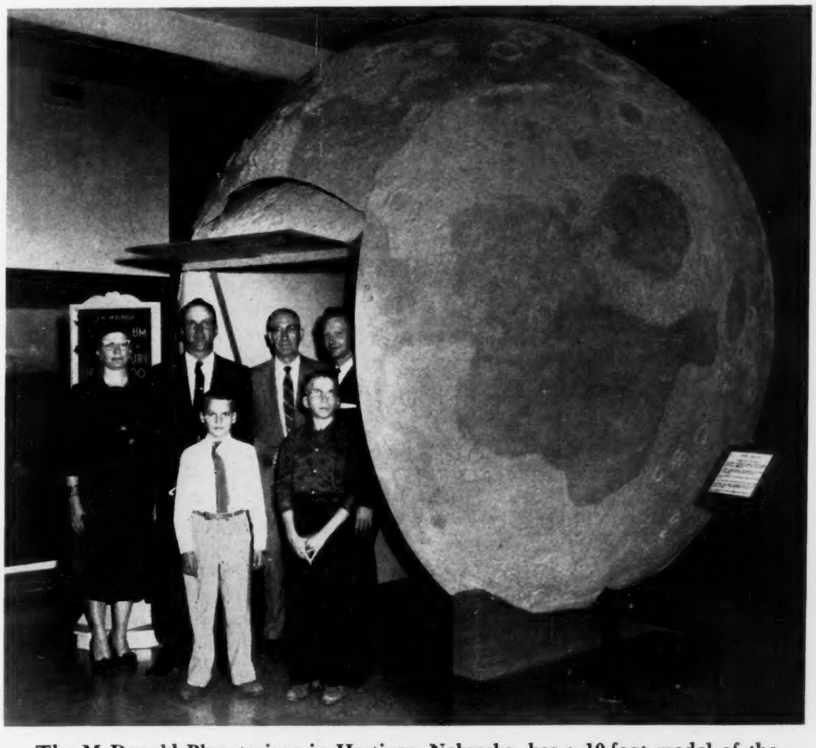
VISITORS to the McDonald Planetarium in the Hastings, Nebraska, Museum have been quite attracted by its entrance, a 10-foot-high model of the moon with a garage-type door cut into it.

The model required the work of four men for five days to place the details on its surface. It was copied from lunar photographs. The overhead door moves on guide rails.

The planetarium was a gift to our city by the J. M. McDonald Foundation, and was dedicated in September, 1958. It houses a Spitz projector under a 24-foot dome, the air-conditioned chamber accommodating 100 children or 75 adults.

There are public showings each day at 4 p.m., with additional demonstrations on Saturday and Sunday at 2 o'clock. School groups are admitted free at times other than the regularly scheduled programs, and we have had classes come from as far as 150 miles away. Each show takes about 45 minutes.

W. E. EIGSTI
McDonald Planetarium
Hastings, Neb.



The McDonald Planetarium in Hastings, Nebraska, has a 10-foot model of the moon for its entry. Hastings Museum photograph.

Planetarium Notes

(Most planetariums give group and special showings by appointment.)

BALTIMORE: *Davis Planetarium.* Maryland Academy of Sciences, Enoch Pratt Library Building, 400 Cathedral St., Baltimore 1, Md., Mulberry 5-2370.
SCHEDULE: (Sept.-June), Thursday, 7:15. 7:45, 9 p.m.; Saturday, 2 and 3 p.m. Admission free. Spitz projector. Director, Paul S. Watson.

BLOOMFIELD HILLS, MICH.: *McMath Planetarium.* Cranbrook Institute of Science, Bloomfield Hills, Mich.
SCHEDULE: Saturday and Sunday, 2:30 and 3:30 p.m.; Wednesday, 4 p.m. Spitz projector. In charge, James A. Fowler.

BOSTON: *Charles Hayden Planetarium.* Museum of Science, Science Park, Boston 14, Mass., Richmond 2-1410.
SCHEDULE: Tuesday through Friday, 11 a.m. and 3 p.m.; Friday, 8 p.m.; Saturday. 11 a.m., 2 and 3:30 p.m.; Sunday, 1:30. 2:45, and 4 p.m. Korkosz projector. Director, John Patterson.

CHAPEL HILL, N. C.: *Morehead Planetarium.* University of North Carolina, Chapel Hill, N. C.
SCHEDULE: Daily, 8:30 p.m.; also at 11 a.m. and 3 p.m. Saturday, 3 and 4 p.m. Sunday. Zeiss projector. Manager, A. F. Jenzano.

CHARLESTON, W. VA.: *Hillis Townsend Planetarium.* Children's Museum, Public Library Building, Charleston, W. Va.
SCHEDULE: Saturday, 11 a.m. Admission free. Spitz projector. Director, Mrs. R. L. Sullivan.

CHATTANOOGA, TENN.: *Clarence T. Jones Observatory.* University of Chattanooga, Brainerd Rd., Chattanooga, Tenn., MA 2-5733.
SCHEDULE: Friday, 8 p.m. Admission free. Jones projector. Astronomer in charge, Karel Hujer.

CHICAGO: *Adler Planetarium.* 900 E. Achsah Bond Dr., Chicago 5, Ill., Wabash 2-1428.
SCHEDULE: Monday through Saturday, 11 a.m. and 3 p.m.; Tuesday and Friday, 8 p.m.; Sunday, 2 and 3:30 p.m.; Tuesday through Friday, 10 a.m., special school program. Zeiss projector. Director, Robert I. Johnson.

COLORADO SPRINGS: *Academy Planetarium.* U. S. Air Force Academy, Colorado Springs, Colo., Granite 2-2779.
SCHEDULE: Wednesday, 8 p.m.; Saturday, 2:30 p.m.; Sunday, 2 and 3:15 p.m. Admission free. Spitz Model B projector. Director, Maj. Richard J. Pfrang.

DALLAS: *Dallas Planetarium.* Dallas Health and Science Museum, Fair Park, Dallas 10, Tex., HA 8-8351.
SCHEDULE: Saturday and Sunday, 3 p.m. Spitz projector. Education co-ordinator, William C. Sibley.

DENVER: *Denver Museum of Natural History Planetarium.* City Park, Denver, Colo., East 2-1808.
SCHEDULE: Saturday and Sunday, 12:30, 1:30, 2:30, and 3:30 p.m.; Monday through Friday, 3:30 p.m. Spitz projector. Curator, Robert E. Samples.

FLINT, MICH.: *Robert T. Longway Planetarium.* Flint Junior College, 1310 E. Kearsley St., Flint 3, Mich., Cedar 8-1631.
SCHEDULE: Tuesday through Sunday, 8 p.m.; Saturday and Sunday, 2 p.m. Spitz Model B projector. Director, Maurice G. Moore.

FT. WORTH: *Charlie M. Noble Planetarium.* Ft. Worth Children's Museum, 1501 Montgomery, Ft. Worth, Tex., PE 2-1461.
SCHEDULE: Saturday, 11 a.m., 2:30 and 3:30 p.m.; Sunday, 2:30 and 3:30 p.m. Spitz projector. Supervisor, Norman C. Cole.

HASTINGS, NEB.: *McDonald Planetarium.* Hastings Museum, Hastings, Neb.
SCHEDULE: Monday through Friday, 4 p.m.; Saturday and Sunday, 2 and 4 p.m. Spitz projector. Director, W. E. Eigsti.

INDIANAPOLIS: *Holcomb Planetarium.* Butler University, Indianapolis 7, Ind.
SCHEDULE: Saturday and Sunday, 4 and 8 p.m. Spitz projector. Director, H. Crull.

KANSAS CITY: *Kansas City Museum Planetarium.* 3218 Gladstone Blvd., Kansas City 23, Mo., Humboldt 3-8000.
SCHEDULE: Saturday and Sunday, 3 p.m. Spitz projector. Director, Wilber E. Phillips.

LANCASTER, PA.: *North Museum and Planetarium.* Franklin and Marshall College, Lancaster, Pa.
SCHEDULE: Tuesday and Thursday, 8 p.m.; Saturday and Sunday, 2 and 3 p.m.; Tuesday, Thursday, and Friday, 9:15 and 10:15 a.m., special school program. Admission free. Spitz projector. Curator, John W. Price.

LAQUEY, MO.: *Tarbell Planetarium.* Inca Cave Park, Laquey, Mo.
SCHEDULE: Sunday, 1 to 6 p.m., continuous. Spitz projector. Director, E. D. Tarbell.

LOS ANGELES: *Griffith Observatory and Planetarium.* Griffith Park, P. O. Box 27787, Los Feliz Station, Los Angeles 27, Calif., Normandy 4-1191.
SCHEDULE: Daily (except Monday), 3:30 and 8:30 p.m.; also 2 p.m. Saturday and Sunday. Zeiss projector. Director, C. H. Cleminshaw.

MEMPHIS, TENN.: *Memphis Museum,* 233 Tilton Rd. at Central Ave., Chickasaw Gardens, Memphis 11, Tenn., GL 2-4732.
SCHEDULE: Saturday, 2 and 2:45 p.m.; Sunday, 2, 2:45, and 3:30 p.m. Admission free. Spitz projector. Educational director, Donn P. Quigley.

MINNEAPOLIS: *Science Museum.* Minneapolis Public Library, 1001 Hennepin Ave., Minneapolis 3, Minn.
SCHEDULE: Saturday, 10 a.m. and 2 p.m. Admission free. Spitz projector. Planetarium director, Mrs. Maxine B. Haarstick.

NASHVILLE, TENN.: *Sudekum Planetarium.* Children's Museum, 724 2nd Ave. S., Nashville 10, Tenn., Chapel 2-1858.
SCHEDULE: Sunday, 2:45, 3:30, 4:15 p.m. Spitz projector. Director, Jacqueline Avent.

NEWARK: *Newark Museum Planetarium.* 49 Washington St., Newark 1, N. J., Mitchell 2-0011.
SCHEDULE: Saturday, Sunday (except 1st Sunday of month), and holidays, 2:30 and 3:30 p.m. Admission free. Spitz projector. Supervisor, Raymond J. Stein.

NEW YORK CITY: *American Museum-Hayden Planetarium.* 81st St. and Central Park West, New York 24, N. Y., Trafalgar 3-1300.
SCHEDULE: Monday, 2 and 3:30 p.m.; Tuesday through Friday, 2, 3:30 and 8:30 p.m.; Saturday, 11 a.m., 1, 2, 3, 4, 5 and 8:30 p.m.; Sunday and holidays, 1, 2, 3, 4, 5 and 8:30 p.m. Zeiss projector. Chairman, J. M. Chamberlain.

PHILADELPHIA: *Fels Planetarium.* Franklin Institute, 20th St. at Benjamin Franklin Parkway, Philadelphia 3, Pa., Locust 4-3600.
SCHEDULE: Tuesday through Sunday, 3 p.m.; Saturday, 11 a.m.; Saturday, Sunday, and holidays, 2 p.m.; Wednesday and Friday, 8 p.m. Zeiss projector. Director, I. M. Levitt.

PITTSBURGH: *Buhl Planetarium and Institute of Popular Science.* Federal and West Ohio Sts., Pittsburgh 12, Pa., Fairfax 1-4300.
SCHEDULE: Daily, 2:15 and 8:30 p.m.; also at 11:15 a.m. Saturday and 4:15 p.m. Sunday. Zeiss projector. Program director, Arthur L. Draper.

PROVIDENCE: *Roger Williams Planetarium.* Roger Williams Park Museum, Providence 5, R. I., Williams 1-5640.
SCHEDULE: Saturday, 3 p.m.; Sunday and holidays, 3 and 4 p.m. (Oct. 1-May 30). Admission free. Spitz projector. Director, Maribelle Cormack.

ST. PETERSBURG, FLA.: *St. Petersburg Junior College Planetarium.* St. Petersburg 10, Fla.
SCHEDULE: Monday, 8 p.m.; Thursday, 4 p.m. (except school holidays). Spitz projector. Director, Elizabeth James.

SAN FRANCISCO: *Morrison Planetarium.* California Academy of Sciences, Golden Gate Park, San Francisco 18, Calif., Bayview 1-5100.
SCHEDULE: Daily (except Monday and Tuesday), 3:30 and 8:30 p.m.; also 2 p.m. Saturday, Sunday, and holidays. Academy projector. Curator, George W. Bunton.

SAN JOSE, CALIF.: *Rosicrucian Planetarium and Science Museum.* Park and Naglee Aves., San Jose, Calif.
SCHEDULE: Sunday and Wednesday, 2 and 3:30 p.m. Spitz projector. Director, Rodman R. Clayson.

SANTA BARBARA, CALIF.: *Gladwin Planetarium.* Museum of Natural History, 2559 Puesta del Sol Rd., Santa Barbara, Calif., WO 6-6720.
SCHEDULE: 1st and 3rd Monday, 3 p.m.; 2nd and 4th Thursday, 8 p.m. Admission free. Spitz projector. Lecturer, C. Adair.

SPRINGFIELD, MASS.: *Seymour Planetarium.* Museum of Natural History, Springfield 5, Mass.
SCHEDULE: Tuesday, Thursday, and Saturday, 3 p.m.; also 8:30 p.m. Tuesday; special star stories for children, Saturday, 2 p.m. Admission free. Korkosz projector. Director, F. Korkosz.

STAMFORD, CONN.: *Edgerton Planetarium.* Stamford Museum and Nature Center, Stamford, Conn., Davis 2-1646.
SCHEDULE: Saturday, 11 a.m. and 3:15 p.m.; Sunday, 4 p.m. Spitz projector. Director, Ernest T. Luhde.

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OBSERVER'S PAGE

Universal time (UT) is used unless otherwise noted.

COMET BURNHAM 1959K

A NEW COMET that will probably be a naked-eye object is to mark the morning sky this spring. This is Comet 1959k, discovered by Robert Burnham, Jr., at Lowell Observatory, Flagstaff, Arizona, on December 30th, when it was a very faint diffuse object in eastern Pisces. It is in retrograde motion around the sun, in an orbit inclined 160 degrees to the ecliptic, according to orbit calculations by B. G. Marsden, Yale University Observatory.

Information for observers is found in Harvard *Announcement Card* 1467 (below). The ephemeris gives the comet's right ascension and declination for selected dates. Columns headed Δ and *r* give distances, in astronomical units, from the earth and sun, respectively. Each magnitude entry has two values, the first for visual observers with small instruments. The other, referring to the comet's nuclear region alone, applies to short-exposure positional photography.

HARVARD COLLEGE OBSERVATORY

ANNOUNCEMENT CARD 1467

Comet Burnham (1959k). — Dr. B. G. Marsden, Yale Observatory, writes: "Improved parabolic elements have been obtained from observations December 30 to January 18. The accompanying ephemeris is intended primarily for the guidance of observers who may wish to plan physical observations during the period of greatest brightness of the comet (perhaps 3^m). Owing to the rather short arc on which the orbit was based the ephemeris may be somewhat in error at the time of the closest approach of the comet to the Earth, and it is therefore hoped that it will be possible to publish a more accurate ephemeris nearer that time."

Elements

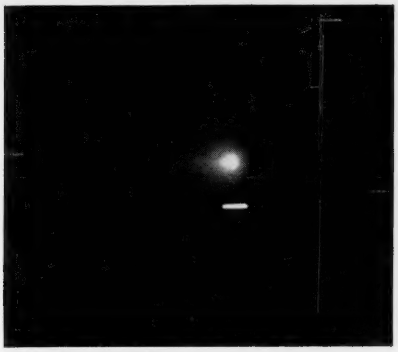
T 1960 March 20.9623 E.T.
q 0.503058

$\left.\begin{array}{l}\omega\ 306^\circ.7438\\ \Omega\ 251.9533\\ i\ 159.5864\end{array}\right\}$ 1950.0

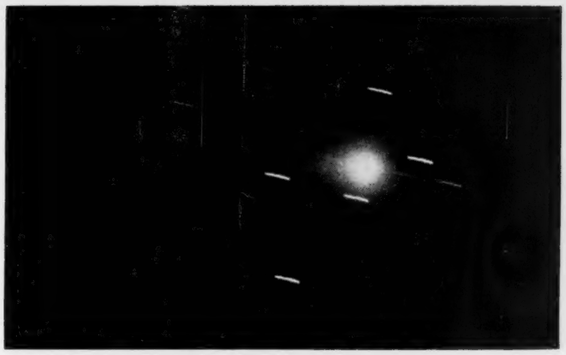
Ephemeris

1960 E.T.		α (h)	(1950.0) (m)	δ (°)		Δ	r	Mag.
Feb.	16.0	0	01.4	− 8	18	1.598	0.918	8,16
	26.0	23	47.7	9	48			
Mar.	7.0	23	32.0	11	15	1.570	0.603	5,14
	17.0	23	12.9	12	21			
	27.0	22	52.6	12	05	1.162	0.524	3,14
Apri.	1.0	22	43.5	10	58			
	6.0	22	35.3	8	50	0.829	0.631	3,15
	11.0	22	27.4	− 5	05			
	16.0	22	18.4	+ 1	46	0.479	0.785	3,15
	18.0	22	13.8	6	10			
	20.0	22	07.7	12	15	0.348	0.851	3,14
	22.0	21	59.1	20	54			
	24.0	21	45.0	33	20	0.242	0.919	3,14
	26.0	21	17.3	50	19			
	27.0	20	50.2	59	57	0.205	0.971	3,13
	28.0	19	59.7	69	12			
	29.0	18	15	76	10	0.212	1.005	3,13
	30.0	15	29	77	39			
May	1.0	13	20	73	57	0.245	1.039	3,13
	2.0	12	32.0	68	53			
	3.0	12	01.8	64	03	0.293	1.073	4,13
	4.0	11	43.9	59	48			
	5.0	11	32.2	56	10	0.352	1.108	5,14
	6.0	11	24.1	53	04			
	8.0	11	13.5	48	08	0.448	1.159	6,14
	10.0	11	07.2	44	24			
	12.0	11	03.0	41	31	0.586	1.226	7,15
	14.0	11	00.2	39	13			
	16.0	10	58.2	37	21	0.727	1.294	8,15
	21.0	10	55.7	33	52			
	26.0	10	55.0	+31	26	1.084	1.459	10,16

January 27, 1960 FRED L. WHIPPLE



Comet Burnham 1959k, on January 18th (left) and 28th, photographed by Elizabeth Roemer with the Naval Observatory's 40-inch reflector. The exposures were 24 and 30 minutes, respectively, and made in blue light. On both reproductions, one millimeter is nearly 10 seconds of arc, or about 7,000 miles at the comet's distance. Official U. S. Navy photographs.



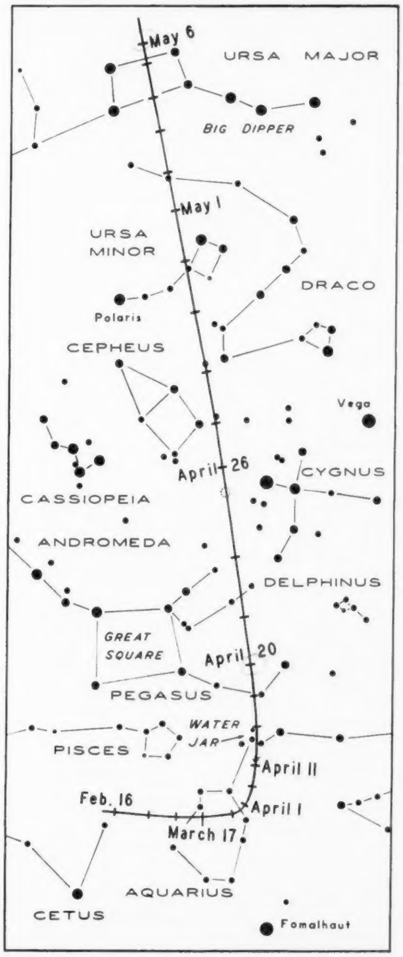
Comet Burnham is approaching the sun, and is to be at a minimum distance of 47 million miles from it on March 20th. At that time, the comet will be in Aquarius and so near the sun in the sky as to be invisible. By the end of March, Comet 1959k will become visible in the morning twilight. While Mr. Marsden has tentatively predicted the magnitude as 3 then, he emphasizes the great uncertainty in any forecast of comet brightnesses; observers should be prepared to find the comet perhaps as faint as magnitude 6.

During April, Comet Burnham will move very rapidly from Aquarius across Pegasus and northeastern Cygnus to the Draco-Ursa Minor boundary by month's end. For observers in latitude 40° north, the comet becomes circumpolar about April 26th, and it will be nearest to the earth (about 20 million miles) on the following day.

Throughout April, the brightness of the comet is expected to change scarcely at all, its increasing distance from the sun being offset by lessening distance from the earth. During 1959k's close approach to the earth, the predicted positions in the sky may be as much as two degrees in error, according to Mr. Marsden, whose ephemeris is based only on observations up to January 18th.

In May, as the comet crosses the bowl of the Big Dipper and enters Leo, it will fade rapidly, since it then will be receding from both the earth and the sun. Nevertheless, it should still be within reach of fair-sized amateur telescopes at the end of that month.

The few early observations available show the beginnings of the expected growth of Comet Burnham. On January 2nd, when Henry Giclas photographed it with the 13-inch refractor of Lowell Observatory, the comet was 14th magnitude, diffuse and without any central condensation. The accompanying photographs



The path of Comet 1959k from February to early May this year, as it passes from the southern sky across the northern circumpolar constellations. Each tick mark indicates the position for one of the ephemeris dates on the facing page. Late in April, when the comet comes closest to Earth, it will appear to move at the unusually fast rate of 10 degrees per day. The cluster in Cygnus near the comet's path in late April is M39.

were taken by Miss Elizabeth Roemer with the Naval Observatory's 40-inch reflector at Flagstaff. On January 18th she could see the comet in the 5-inch finder as a diffuse patch of the 12th magnitude. Visually, the 40-inch telescope showed a faint starlike nucleus, imbedded asymmetrically in an area of light two or three minutes of arc in diameter. By the 28th the comet had two tails — one short and curved, the other long, narrow, and straight — and was magnitude 10.5 to 11.

Amateur observers should plan to take advantage of the exceptionally favorable circumstances of visibility presented by Comet 1959k. It is seldom that a comet this bright will remain conveniently placed in high declination for several weeks. Photographers will find this an excellent opportunity for a long sequence of night-by-night pictures.

Several suggestions can be offered to visual observers. Those with experience in variable star work are urged to make careful estimations of the brightness of the comet, using binoculars out of focus, so that the images of the comet and comparison stars are similar. Another project is to keep a systematic record of the dimensions of the head and the length of the tail; these may be estimated directly in minutes of arc, using the size of the telescopic field of view as a standard. Third, the rapid motion of the comet across the Milky Way in Cygnus provides a favorable opportunity for watching the passage of the comet in front of stars. Careful records of such observations are valuable, particularly with large-aperture telescopes.

URSID METEORS OBSERVED

On the three nights beginning December 20-21, 1959, I watched for the Ursid meteor shower. On the 20-21, two 5th-magnitude Ursids were seen, but there were none the next night. The height of the shower was on the 22-23, when I carried out several observing periods.

During the half hour starting at 0:30 Universal time, two faint meteors came from the Ursid radiant. One of zero magnitude passed between Ursa Minor and Cygnus at 2:59, leaving a train visible for $1\frac{1}{2}$ seconds. This was the fifth Ursid during the 15 minutes beginning at 2:45 UT. From 3:00 to 4:00, 14 meteors were seen, including one of the 1st and one of the 3rd magnitude. Twenty-one more were counted from 4:00 to 5:10.

Most of the meteors recorded during this shower were very faint, and had the sky not been so transparent the observed rate would have been very low. The meteors counted as Ursids came from two radiants: one about a degree southeast of Beta Ursae Minoris, the other about three degrees east of Epsilon Ursae Minoris.

CRAIG L. JOHNSON
765 S. 46th St.
Boulder, Colo.

The clusters M35 (center) and NGC 2158, here photographed with Palomar Observatory's 48-inch Schmidt camera, are strikingly different in appearance. The width of the field is slightly over two degrees, and south is at the top.

DEEP-SKY WONDERS

THE COMPILER of a sky atlas must call a halt at some magnitude limit, and this cutoff may control the experiences of several generations of observers. Such was the case with the star cluster M35 and its faint neighbor, NGC 2158. Norton's *Star Atlas* does not include the latter, and many amateur astronomers have grown up knowing nothing of it. The brief mention of NGC 2158 in T. W. Webb's *Celestial Objects* seems to have been generally overlooked.

In recent years, telescopes of 10-inch aperture and larger have become common, so their owners began to detect the faint cluster. Often they thought they had a new comet. This was my experience in 1957, and also, about the same time, of O. R. Norton, Long Beach, California, and Edgar Everhart, Mansfield Center, Connecticut. Some amateurs had logged it earlier – for example, Robert Burnham, Jr., of Prescott, Arizona, and Leonard B. Abbey, Jr., Decatur, Georgia. Others first saw it after the mention in this department in April, 1957.

M35 itself is a magnificent open cluster at right ascension $6^h\ 05^m.7$, declination $+24°\ 20'$ (1950 co-ordinates), not far from Eta Geminorum. Well known as a test object in the winter skies, it is actually a naked-eye cluster, of the 6th magnitude. Its diameter is variously listed from 33′ to 44′, but in my 10-inch it seems almost 60′, with the ghostly NGC 2158 near its outer fringe.

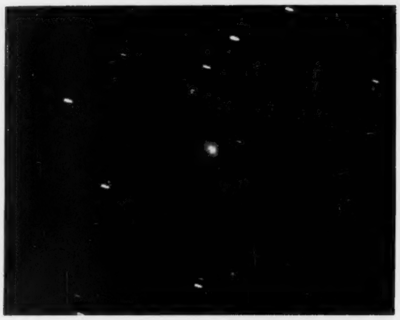
One of my favorites, M35 is visually an impressive frame of bright stars with a softly flaming background of fainter ones, seemingly containing hundreds of members. The 10-inch shows it as diamond-shaped.

The fainter cluster, NGC 2158, is catalogued as magnitude 12.5, but different observers seldom agree on cluster magnitudes, and I think it is brighter. It is generally too difficult for apertures of less than five inches, and I have received only one report of its being seen in a 4-inch. In the 10-inch at 90x, it has a soft sheen, totally unlike the Messier object, and resembles a diffuse nebula or a comet. Mr. Abbey, using a 16-inch at 300x, resolves this faint cluster into stars.

With a 120-mm. 20x Moonwatch apogee telescope, M35 is a bright, bold triangle, but changes to the larger diamond when viewed by averted vision. And NGC 2158 is just visible, well outside the edge of M35. In this instrument's large field – over two degrees – this region presents a memorable sight, and shows traces of dark areas to the east.

Photographs by E. E. Barnard and others do not match the visual appearance of either cluster. The Ross-Calvert *Atlas of the Northern Milky Way* comes closest, while S. R. B. Cooke's photograph with a 6-inch Schmidt camera barely shows NGC 2158. It is more distinct in the accompanying Palomar Schmidt picture than in any other I have seen. Though I have viewed this region many times since 1957, I have never seen the little cluster appearing as round and regular as depicted here. George Keene, Rochester, New York, draws it with the same irregularities in shape that I see.

WALTER SCOTT HOUSTON
Rte. 3, Manhattan, Kans.



The first comet of 1960, found by Robert Burnham, Jr., of Lowell Observatory.

ANOTHER COMET BURNHAM

Only about three weeks after he discovered Comet 1959k, Robert Burnham, Jr., found another, 1960a. According to an observation by Henry L. Giclas at Lowell Observatory, reported in Harvard *Announcement Card* 1468, the comet was in Taurus, and of magnitude 14, on the evening of January 20th.

That same night, 1960a was photographed by B. A. Smith and A. S. Murrell of New Mexico State University, with a 12-inch f/6.7 reflector. On the original negative of their picture reproduced here, the comet's tail is about eight minutes of arc long. They used 103a-O emulsion for an 18-minute exposure. The comet was moving almost due northward about half a degree per day.

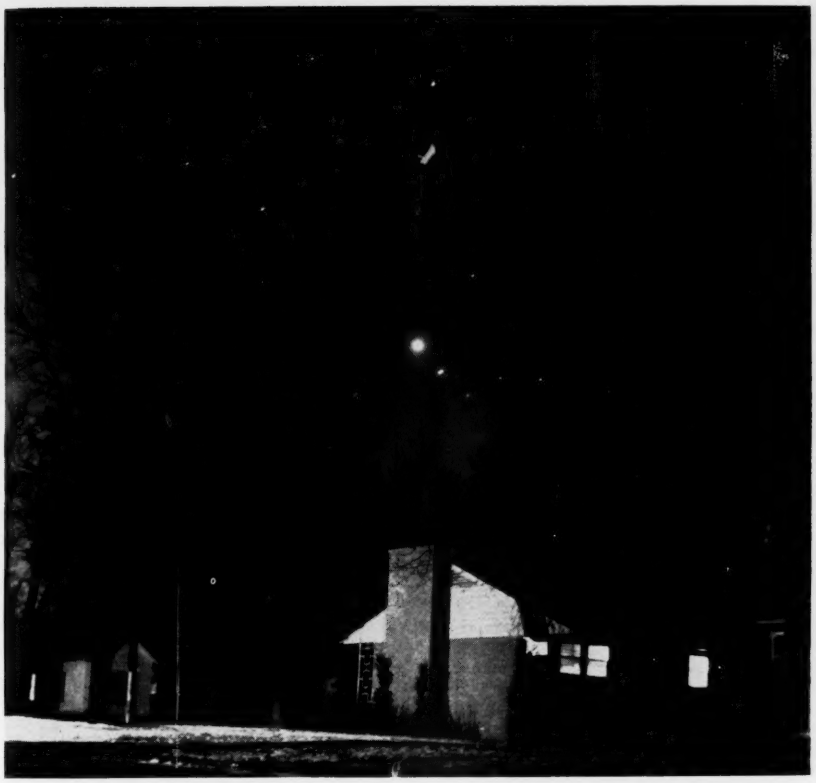
This is the sixth comet that Mr. Burnham has discovered. It is a by-product of the survey with the 13-inch telescope for stars with large proper motions, the new plates being compared with those taken in the search for the planet Pluto 30 years ago (see page 264).

CELESTIAL SHADOWS

"If space were slightly dusty, we would see that all the planets and their satellites cast long conical shadows like great black dunce caps, pointing exactly away from the sun."

Thus writes C. H. Cleminshaw in the October, 1959, issue of the *Griffith Observer,* about the sizes of the shadows of the earth, moon, and planets, and their relation to eclipses of various kinds. The longest planetary shadow, that of Neptune, would more than span the space from the sun to the earth, and even Pluto has a shadow 17 million miles long, on the assumption that its diameter is 4,000 miles.

Jupiter's average shadow is 55 million miles in length, Saturn's 83 million, while Mercury's is only 125,000 miles long. Venus, the earth, and Mars are all less than a million miles, whereas two of Jupiter's satellites have 1,800,000-mile shadows. Our own moon has a rather short shadow, averaging 232,000 miles, but long enough to strike the earth occasionally and produce a total eclipse of the sun.



At Independence, Kansas, at 6:20 a.m. Central standard time, Jack Hills made this 20-second photograph with an f/2.5 Aero-Ektar 3-inch lens. Venus (overexposed image) and Jupiter were about an hour past conjunction.

VENUS-JUPITER CONJUNCTION

When Venus, magnitude −3.5, passed only a degree north of Jupiter, −1.4, on the morning of January 21st, they made a striking sight in the eastern dawn sky. Edward V. Vyborny, at Berwyn, Illinois, took a series of 35-mm. Kodachromes that week, and on January 23rd recorded the two planets, the moon, and Antares all in one picture.

SUNSPOT NUMBERS

The following American sunspot numbers for December, 1959, have been derived by Dr. Sarah J. Hill, Whitin Observatory, Wellesley College, from AAVSO Solar Division observations.

December 1, 164; **2**, 192; **3**, 194; **4**, 174; **5**, 155; **6**, 152; **7**, 131; **8**, 138; **9**, 97; **10**, 76; **11**, 72; **12**, 74; **13**, 79; **14**, 82; **15**, 120; **16**, 108; **17**, 105; **18**, 131; **19**, 163; **20**, 174; **21**, 154; **22**, 116; **23**, 110; **24**, 121; **25**, 143; **26**, 134; **27**, 150; **28**, 153; **29**, 120; **30**, 113; **31**, 131. Mean for December, 129.9.

Below are provisional mean relative sunspot numbers for January by Dr. M. Waldmeier, director of Zurich Observatory, from observations there and at its stations at Locarno and Arosa.

January 1, 136; **2**, 110; **3**, 133; **4**, 156; **5**, 158; **6**, 174; **7**, 167; **8**, 153; **9**, 150; **10**, 127; **11**, 143; **12**, 108; **13**, 108; **14**, 118; **15**, 112; **16**, 119; **17**, 117; **18**, 89; **19**, 80; **20**, 94; **21**, 103; **22**, 134; **23**, 138; **24**, 130; **25**, 152; **26**, 209; **27**, 186; **28**, 159; **29**, 193; **30**, 178; **31**, 178. Mean for January, 139.1.

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BOOKS AND THE SKY

OUR SUN

Donald H. Menzel. Harvard University Press, Cambridge, Mass., 1959. 350 pages. $7.50.

IN 1949 Professor Menzel's *Our Sun* was published as one of the Harvard books on astronomy. It was intended to describe and consider the problems of solar physics in a way that would be understandable to the nonspecialist. The book quickly established a secure place on the required reading lists for all who professed anything more than a casual interest in science. The present edition is a detailed revision of the earlier work.

The changes are numerous. Two new chapters have been added: "The Sun and the Universe," in which Dr. Menzel considers the relationship of the sun to the other stars; and "Solar Power and Human Needs," in which the possibilities of solar radiation as a source of power are explored. The final chapter, "The Sun and the Earth," very profitably uses material from the author's *Elementary Manual of Radio Propagation* and *Flying Saucers* to effect a complete revision of the corresponding section in the 1949 edition. It is a great improvement.

The illustrations are among the best this reviewer has seen reproduced by the photo-offset process, and the book in general has a pleasing appearance. However, the reproductions in many instances still do not do justice to the originals. Approximately one-third of these illustrations are new and, for the most part, replace less adequate photographs.

In many respects, it is relatively easy to review a new edition of a book whose value has been well established for many years. But how closely has the author, when presented the opportunity for revision, heeded the admonition in *I Thessalonians 5:21*? Perhaps a few good things may have been discarded in the revision, and all new material may not have been proved.

It might have been pointed out in discussing the possibility of a variation in the sun's diameter that astronomers have great difficulty in measuring the diameters of most celestial objects. Even the moon, which has an extremely sharp edge and thus might be expected to be the most easily measured of all, behaves in a puzzling fashion. A different diameter must be used for the prediction of occultations from that which is used for the prediction of eclipses!

Throughout the book emphasis is placed entirely on solar activity, perhaps leaving the reader with a seriously incorrect impression of the sun's nature. Most of the time the sun is extremely well behaved, and even during maximum activity there are many days when the closest scrutiny under the very best observing conditions is rewarded by the detection of only very small changes. Obviously these are not the spectacular events astronomers like to show in their photographs or to discuss, but perhaps we should be thankful that the sun is usually a pretty quiescent object.

A similarly incorrect impression may be given concerning high-latitude sunspots. Not infrequent small spots, lasting for a few hours, have been observed at extremely high latitudes. The first spot in the solar cycle that began in 1915 appeared at latitude 60°, the first spot in the 1846 cycle at 50°. It is true, however, that an unusual number of long-lived spots were seen at latitudes greater than 40° during the present cycle, No. 19.

Although Fig. 65, which shows the equatorial acceleration of the sun's rotation, is a schematic diagram, it underestimates this effect.

The veiled sunspots first reported by L. Trouvelot are now receiving an abnormal amount of attention by Soviet and German astronomers. By convention, sunspot observers do not report the gray markings often discernible on the solar disk and in fairly great abundance in and around the spots. Mount Wilson Observatory records such markings wherever they occur on the disk, but as far as this reviewer is aware only casual reports have been published.

In regard to circulation above sunspots, slightly contradictory accounts are given. On page 120 it is indicated that observations suggest that there exists over sunspots a "sort of flattened smoke ring vortex with outflowing gases in its lower part and inflowing gases in the upper regions." Yet on page 127, it is said, "the rising gas, therefore, cannot flow horizontally and descend again to complete the convecting cycle. As a result spots are calm regions in an otherwise turbulent atmosphere." It remains a question how to reconcile the apparent observation of convective currents above sunspots and our feeling that such motions should be strongly inhibited by the presence of magnetic fields in the spots. The vortex structures pointed out by the author in a hydrogen spectroheliogram can hardly be simultaneous evidence for the presence and absence of convective currents.

In the description of the fine details of the solar surface, a short discussion is given of the appearance of bright helium in emission near sunspots. Unfortunately, the example in the photograph Fig. 91A shows helium in emission in the flare of July 25, 1946. This was a most unusual event and it was a most unusual flare. Surely, it should not be quoted as an indication of such emission in any reasonably normal part of the solar surface. Helium does appear frequently in absorption in the bright plage regions;

however, as far as we know, helium never appears in bright emission on the solar disk, except in a flare.

The first picture (Fig. 108A) of the eruptive prominence of June 4, 1946, indicates that it was made at 16:03 Universal time, or 09:03 Mountain standard time. The photograph could hardly have been taken shortly after sunrise (04:30 MST) as stated in the text.

Both old and new editions contain an excellent summary of solar eclipses, arranged by saros cycles. Recent developments in the periodicities of eclipse occurrences are probably wisely omitted. The detailed regularities now known are so numerous and complicated that to list them all would undoubtedly be confusing.

In the section on the uses of solar energy, the reviewer was struck by the omission of any reference to solar heat for cooling. Important developments are being made in this field. Since it is nearly always hottest when the sun shines, the most energy is available for cooling just when one needs it.

In the discourse on the terrestrial effects of solar activity, there seems to be no reference to the two types of magnetic storms: sporadic storms that start suddenly, and recurrent ones that start gradually. Recognition of these two classes of terrestrial disturbance is of great assistance when one attempts to determine the solar causes for the events that we record.

The paragraphs above are a listing of the more important possible defects of the new edition of *Our Sun,* but they are hardly serious. Dr. Menzel's revision has resulted in a good book. There are many controversial statements of varying degrees of subtlety to prompt readers at all stages of astronomical erudition to write in the adequate margins and to underline statements where they agree or take exception. It conveys some of the challenge of the solar problems whose solutions seem always to be just in sight, but never quite apprehendable.

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CLOSE BINARY SYSTEMS

Zdenek Kopal. John Wiley and Sons, New York, 1959. 558 pages. $16.75.

WHILE the title of this book is *Close Binary Systems,* it has a more limited objective than a complete description of this field. As the author points out in the closing words of the introduction, his chief purpose is to earn for his equilibrium model a "permanent place in the existing literature of double-star astronomy."

The volume starts with an introduction that traces some of the early history of binary star studies, and then describes the general outline to be followed. Chapter II is an effort to cope with the dynamical phenomena shown by close binaries, and departs from the older methods by not assuming that the axis of rotation is parallel to the axis of revolution. Chapter III discusses the conventional Roche model and equipotential surfaces, and IV explores the theoretical light changes from various causes in close binary systems. Chapter V treats theoretical velocity changes, such as rotational effects during eclipse, and the effects of reflection on radial velocity.

Determining the elements of an eclipsing binary system is the subject of Chapter VI. H. N. Russell's method is presented in less than four pages, and Kopal's in 43. He severely criticizes Russell's work, but his criticisms actually apply not to the method itself, but to its misuse by some computers. Also included in this chapter is a discussion of the influence of a possible third body on the solution. Here the author seems unaware of the earlier comprehensive treatment by Russell and J. Merrill in Princeton University Observatory *Contribution* No. 26 (1952). The most useful sections of the chapter are those dealing with eccentric orbits (pages 383-399). The closing chapter is on the physical properties of close binary systems.

It is rather difficult to give a precise evaluation of this volume. The treatment

is entirely mathematical, with little feeling for physical realities. Thus, in its present form, it is not suitable for application to actual observations. I have not checked on the accuracy of all the many equations, but it is not reassuring to be told (page 146) that much of Chapter III is a rediscussion of an earlier paper by Kopal which "contained, unfortunately, many slips and misprints which have been corrected in its present version," and then to find errors in three of the first four equations in the chapter.

A good deal of the material in the book is not new, and it could have been shortened considerably by judicious reference to the existing literature. Indeed, the most serious criticism is that the author overlooks earlier studies. In general, reference to previous work appears only in bibliographical notes, and the over-all impression given by the text is that all the material is original. For example, G. P. Kuiper's 1941 study of Beta Lyrae first presented the dynamics of shells or gas streams around close binaries, and contained many of the more important ideas concerning this in the present book. Yet there is only a clause in the bibliographical notes about this work of Kuiper's; the same is true of a paper by Kuiper and J. R. Johnson in 1956, which anticipates much of the material in Chapter III.

In the discussion of atmospheric eclipses, no mention is made of S. Gaposchkin, who first suggested the possibility of this phenomenon for Zeta Aurigae, nor of F. E. Roach, who applied the suggestion to observational material. The theoretical work of A. P. Linnell is likewise overlooked.

Similar omissions occur in other sections. The consideration of matter ejected from unstable components ignores the papers by various investigators at the University of California in Berkeley. The statement on page 546, "A demonstration that the fractional dimensions of the secondary components in semi-detached eclipsing systems coincide with their Roche limit within the limits of observational errors was not given until by Z. Kopal in *Annales d'Astrophysique, 18,* 393, 1955," is not true. A discussion of precisely this (though the word "semi-detached" was not used) is to be found in the *Astrophysical Journal, 112,* 196, 1950. The discovery on page 468 that systems classified as Algol or Beta Lyrae types may be similar physically was also anticipated in the 1950 article.

The most important modern development in the theoretical treatment of light curves, the Merrill nomographs, is not treated at all. There are curious criticisms of the late Henry Norris Russell on pages 291 and 447. Russell's papers generally did not contain "slips and misprints," nor are they difficult for astronomers to follow.

The brief sections on handling observational data contain various errors, even

though much of this is previously published material. Page 299 states that seeing errors are proportional to a star's brightness, and the light curve on page 303 has a distorted time scale that gives an erroneous impression of the nature of the system. On page 443, the author argues for the separation of the observer and the computer partly because of the "complexity" of "intricate photoelectric techniques." The statement might have been true 20 years ago, when photoelectric photometers were temperamental devices requiring the attention of experts, but the bulk of the useful photoelectric work today is being carried out by astronomers with no special training in electrical engineering.

On page 147, the author speculates on the election of a patron saint by students of eclipsing variables. For reasons not made clear, this turns out to be Anaxagoras, a pagan.

Close Binary Systems has the general weakness of being a series of monographs on selected specialized topics, rather than a complete coverage. Further, its treatment of spectrographic material is inadequate, yet from this has come most of the important ideas in the modern state of the subject.

Had this book been published in the 1930's, most of its material would have been new, and relevant to observations of the precision that we *then* hoped to attain in the future. We now know that because of the uncertainties introduced by our own atmosphere, and especially because of fluctuations in the stars themselves, we probably will never be able to carry out this type of analysis to the precision we once hoped. For real progress in our understanding of close binary systems, our great present need is an entirely new treatment, one that considers the stars as physical realities instead of merely geometrical disks and that takes proper account of the complications known to affect these systems.

Actually, the real excitement of modern work lies in the study of these very changes that largely vitiate the usefulness of overly complex models. Instead of ignoring the realities discovered by spectrographic and photometric observations of the past 20 years, we should be stimulated by them. By their very departures from our simplified models, the stars are sending us information about their origin and evolution. Of course, we must still compute the fundamental elements to reasonable precision, by methods that do not need unreasonable labor, so that our knowledge of stellar properties does not lag behind the observational material. Thus, from careful observation and realistic analysis of all the available data, slowly over the years we may gain better understanding of close double stars and of stars in general.

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NEW BOOKS RECEIVED

FERNROHRMONTIERUNGEN UND IHRE SCHUTZBAUTEN FUR STERNFREUNDE, *Anton Staus,* 1959, *UNI-Druck,* Amalienstr. 85, Munich 13, W. Germany. 67 pages. DM 8.

Telescope Mountings and Their Shelters for Amateur Astronomers contains complete directions for making four telescope mounts, suitable for refractors of 2- to 6-inch aperture, or reflectors of similar weight. Instructions in German are provided for the erection of small observatories with sliding roofs, and pyramidal and semispherical domes. There are numerous illustrations, and a pocket inside the front cover contains dozens of large folded sheets of detailed plans.

THE OCEAN OF AIR, *David I. Blumenstock,* 1959, *Rutgers University Press.* 457 pages. $6.75.

An American meteorologist tells in easy-to-read language how the earth's atmosphere and weather affect man's activities in many ways. Some of the aspects described are weather control, forecasting, rainfall and agriculture, and radioactive fallout.

ARABISCHE STERNNAMEN IN EUROPA, *Paul Kunitzsch,* 1959, *Verlag Otto Harrassowitz,* Taunusstr. 5, Wiesbaden, W. Germany. 240 pages. DM 28, paper bound.

Arabic Star Names in Europe contains detailed histories of the names of over 200 stars, tracing their changes over the centuries to their present forms. Extensive critical notes and bibliographies are features of the text, which is in German.

SELENE, *Rubens de Azevedo,* 1959, *Edicoes Pincar Ltda.,* Caixa Postal 5391, Sao Paulo, Brazil. 144 pages. 150 cruzeiros, paper bound.

This well-illustrated book about the moon, written by a Brazilian amateur observer, is similar in level and scope to the shorter works by Patrick Moore and H. P. Wilkins. Many drawings accompany the text, which is in the Portuguese language.

THE OBSERVER'S HANDBOOK 1960, *Ruth J. Northcott,* editor, 1959, *Royal Astronomical Society of Canada,* 252 College St., Toronto 2B, Ontario. 87 pages. 75 cents, paper bound.

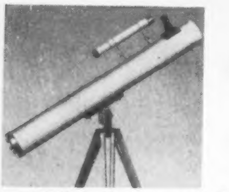
This is the 52nd annual edition of this valuable aid for the amateur astronomer. It contains monthly listings of phenomena, including data on the sun, moon, planets, Jupiter's satellites, and meteor showers for 1960. Tables for the rising and setting times of the sun and moon are given, as well as variable star and occultation predictions. There are compilations of information on double stars, clusters, nebulae, and galaxies suitable for amateur observing. The 286 stars brighter than magnitude 3.55 are listed, with their colors, spectral types, motions, distances, and absolute magnitudes.

INTRODUCTION TO THE MECHANICS OF THE SOLAR SYSTEM, *Rudolf Kurth,* 1959, *Pergamon.* 177 pages. $6.50.

A University of Manchester astronomer here presents the fundamental principles of celestial mechanics on the advanced undergraduate level. Vector notation has been used extensively.

MAN'S REACH INTO SPACE, *Roy A. Gallant,* 1959, *Garden City Books.* 152 pages. $3.50.

The biological problems man faces in his attempts to leave the earth are described in this well-illustrated book for teen-agers.



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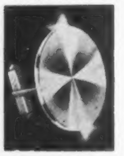

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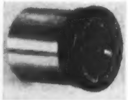

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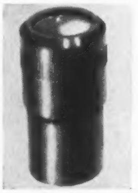

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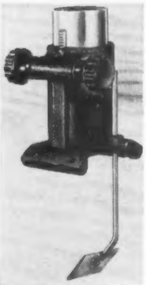

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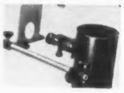

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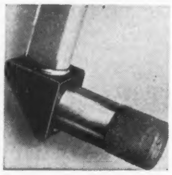

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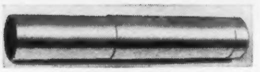

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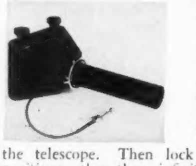

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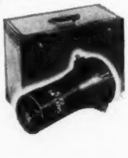

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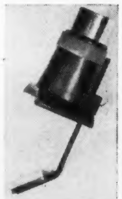

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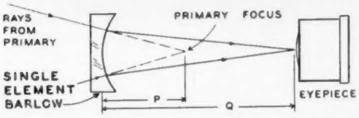

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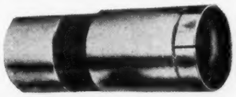

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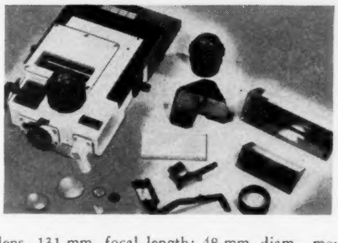

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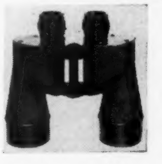

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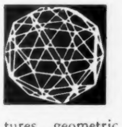

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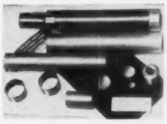

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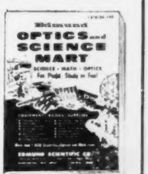

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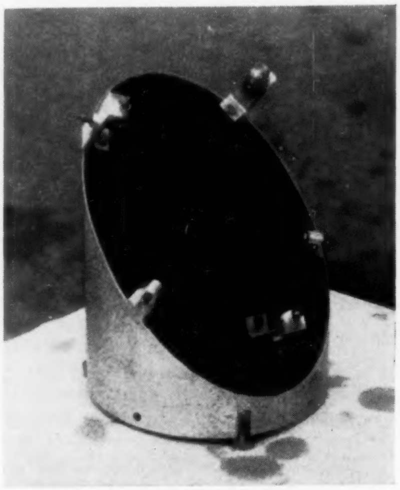
A 20-inch Reflector Built in Brazil — II

To attain fully the potentialities of a large instrument like the 20-inch Newtonian-Cassegrainian reflector whose mounting and drive mechanism were described here last month, much care must be devoted to designing and constructing the supporting system for the primary mirror.

The outer mirror-cell casing is a spun-copper pan lined with fiberglass wool for thermal insulation. Inside of this is placed the main cell casting of aluminum, which is shown in the photograph opposite holding a plastic dummy mirror 20″ in diameter and 3½″ thick. The adjusting screws and lock nuts of the radial counterweight system are seen around the outside of this casting.

A top view of the interior of the casting (below) clearly shows the 12 counterweighted levers that support the radial component of the mirror's weight, as well as 12 of the flotation support system's 18 pads. These are connected by a series of triangular supports and levers in such a way that the axial component of the mirror's weight is always automatically and evenly distributed.

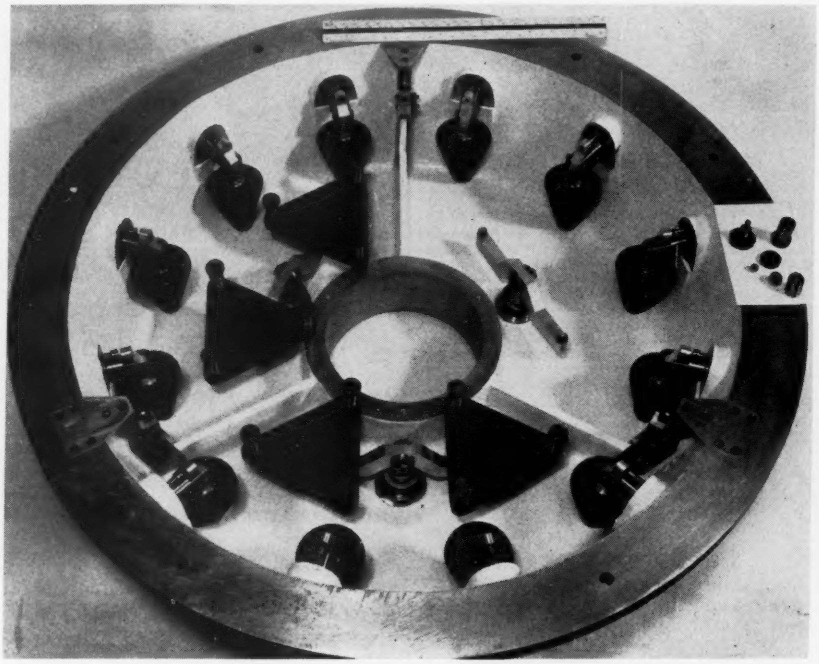
Set temporarily on the right-hand edge of the casting are sample parts of the radial and axial pads, designed so they transmit pressure along their length but not sideways. This is to permit freedom of mirror movement (without slipping)



The Newtonian diagonal holder for the 20-inch telescope. All pictures with this article are the author's.

at right angles to the surface of each pressure pad. Thus, the axial supports offer no restraint in a radial direction, while the radial supports (around the mirror's periphery) do not restrain the axial component of the mirror's motion.

To achieve this, each nonrestraint pad consists of a pair of hardened ground steel buttons, separated by a steel ball, the three parts being held together with



The 20-inch mirror cell, showing the levers around the inside wall that support the radial component of the mirror's weight, and the flotation support system (on the bottom of the cell) that bears the axial component. Jutting in from the sides, over the ribs in the base, are the three mirror-locating studs.

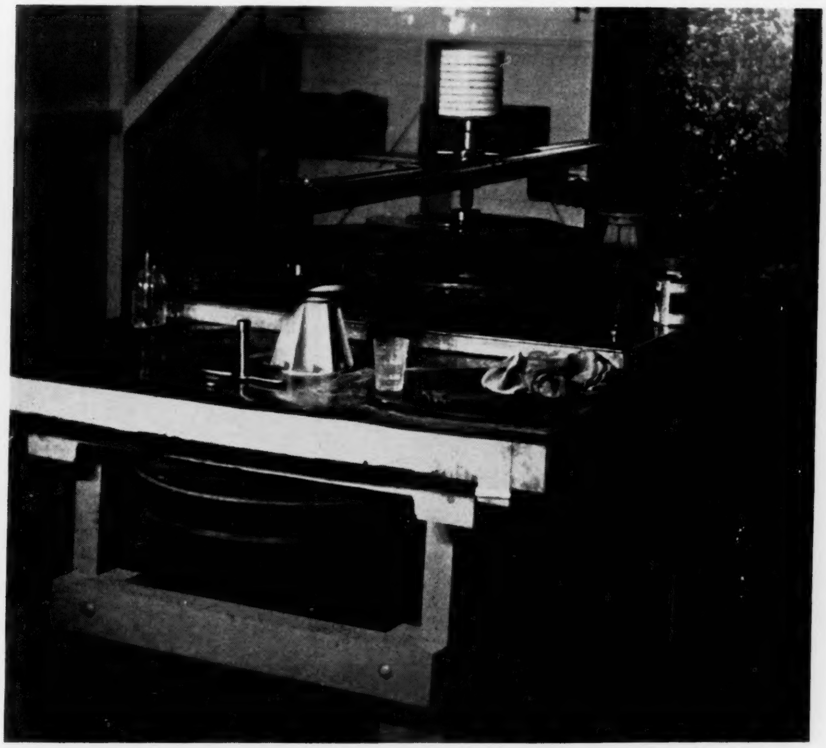
A side view of the mirror cell, with the plastic dummy mirror in place. Beneath the rim are seen the fastenings that hold the radial pads to the side of the cell. The small holes in the rim are for the bolts to the main tube.

an enclosing spring. A lead cap on the end of this assembly comes in contact with the mirror. Supports with large caps are used in the radial system, but unfortunately none of these were in place when the photograph was taken. They screw into the small hole at the top of each of the 12 lever systems, the other end of the lever carrying one of the lead counterweights, which appear here as black truncated cones.

Spaced 120° apart, three mirror-locating studs jut out from the edge of the casting. The tubular Cassegrainian mask or light shield bolts onto the round metal piece that is seen inserted in the center of the casting. The whiffletrees (one of three is visible) that carry the axial support spiders are equipped with threaded bushings for leveling and collimating the mirror. Around the rim of the casting are holes for bolting the mirror cell to the main telescope tube.

A set of six wedge-shaped cover plates, located immediately above the mirror in the central barrel of the main tube, forms a mirror cover when the instrument is not in use. They are operated by a hand lever extending through the central barrel.

A large part of the time spent in building this telescope was applied to developing the grinding and polishing machine. All its parts were specially made. It had pulleys of various sizes, so a number of rotation speeds could be obtained. The spindle carrying the grind-



The grinding and polishing machine with the 20-inch blank in place. The blank turns at 1½ r.p.m., the far eccentric crankshaft at 4.6, and the near one at 28 r.p.m. The throw of the crankshafts is adjustable from zero to 11″.

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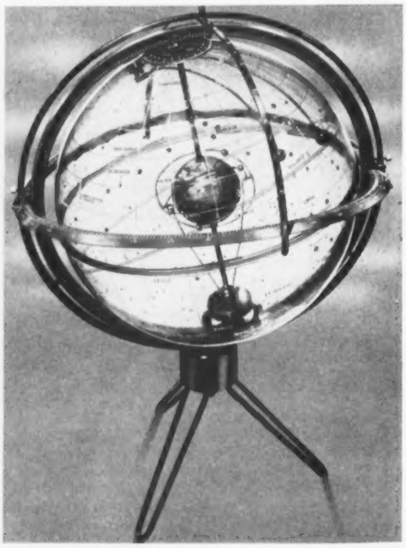

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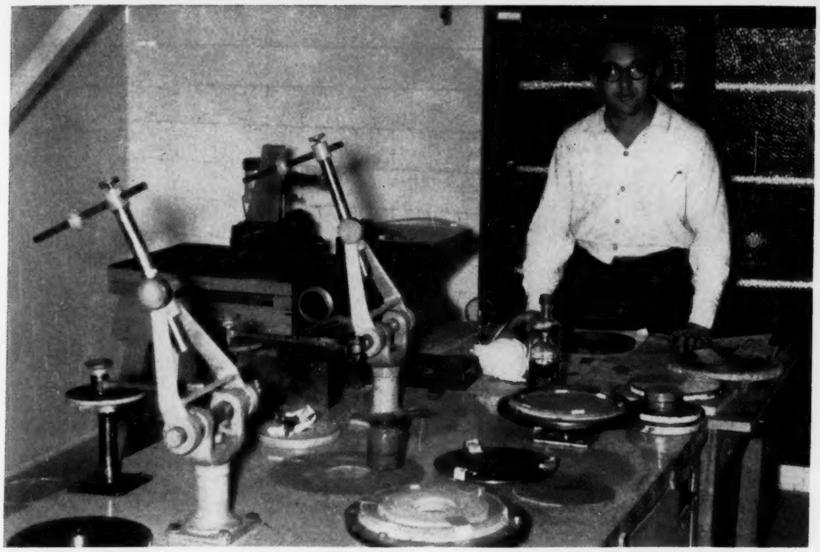
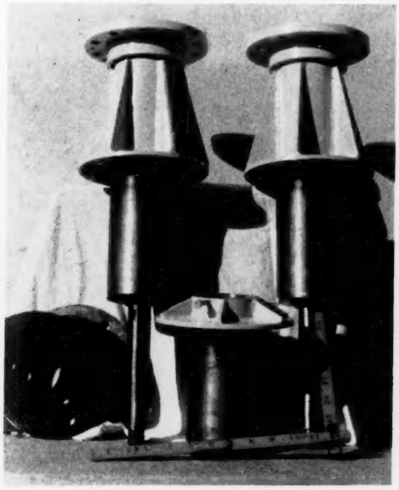


Optician Abram Szulc ready for work on the refractor lens elements. The blanks are mounted on the turntables in the right foreground, and the tools on the jigs at the left. In the background is the Foucault testing apparatus.

ing and polishing tools could be placed in any position along the oscillating bridge. The tool spindle could move up and down freely in the spindle bearing, while the tool itself swiveled freely on the spindle. Lead disks on the upper end provided any desired loading of the tool.

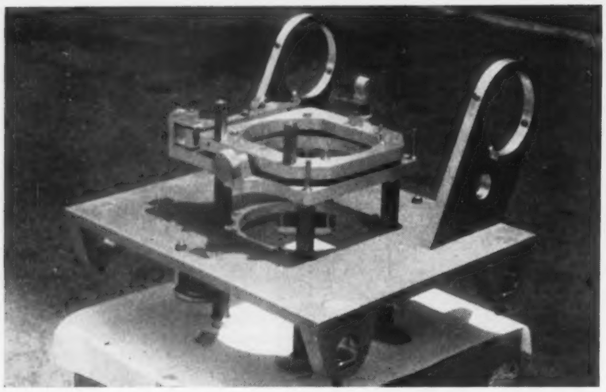
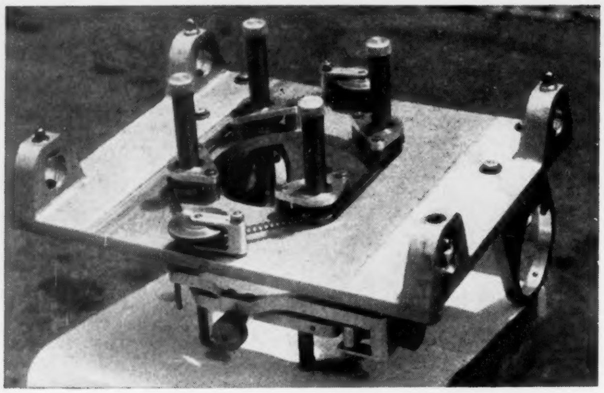
My collaborator, A. Szulc, has an exceptional knowledge of optics. He and I realized from the start that telescopes can be no better than their optical elements. We sought to make up for our lack of actual experience with such a large mirror by a lavish expenditure of time and patience. This was necessary for the 8-inch refractor as well, for that is a fair-sized astronomical instrument and four surfaces had to be ground, polished,



Parts of the grinding machine. The tall pieces are the crankshafts, the small ones their support quills. These are just a few of more than 50 castings made for the grinding machine and the two telescopes.

and figured to produce the achromatic lens.

The two-element objective is air spaced to provide the best correction for aberrations. The objective cell is in two parts, one rigidly affixed to the refractor's tube. The other carries the two glass elements, supported on three lead pads that are in-

The Newtonian ocular stage in two views. Its outer side (left) carries two large brackets to accommodate the finder. On its inner side (right) is the ladder chain that drives the movable plates along the optical axis by means of four threaded pillars. The four eye brackets are for mounting the apparatus at the upper end of the telescope tube.

dependently adjustable in a direction transverse to the axis of the cell. Because this inner part of the cell is supported at only three points, it can be tilted slightly with respect to the outer one, permitting perfect alignment of the lens. An ocular stage similar to those used in the main instrument is mounted on the lower end of the refractor's duralumin tube.

Special ocular stages are provided at both the Newtonian and Cassegrainian foci to permit the use of eyepieces or photographic plates with precision control of focusing and guiding. Each stage consists of three plates, one serving as the base and two that can be moved. Four threaded pillars allow the outer two stages to be moved in and out along the optical axis of the telescope. This is accomplished by means of an endless ladder chain passing around sprocket wheels on the pillars and a pair of knurled focusing knobs under the base plate. The upper movable plate may also be rotated and moved horizontally in two directions, so a guide star just outside the area being photographed may be used, and fine guiding may be done by moving the plateholder itself.

My personal effort during this project included all the mechanical design of the telescope itself, plus the clock drive, grinding machine, tooling and testing apparatus, and auxiliary equipment. It was necessary to produce complete design drawings of every part, to fabricate more than 50 foundry patterns, and carry out a large amount of machine work.

This "amateur" project was professional in its approach, even going beyond the standards of most commercial manufacturers, for they could not justify so large an expenditure of engineering time, nor pass its cost along to the customer. Materials alone cost more than $4,000 for

each of the two identical instruments, and more than 18,000 hours of time were recorded, not counting drafting and engineering design or the long hours in the optical shop.

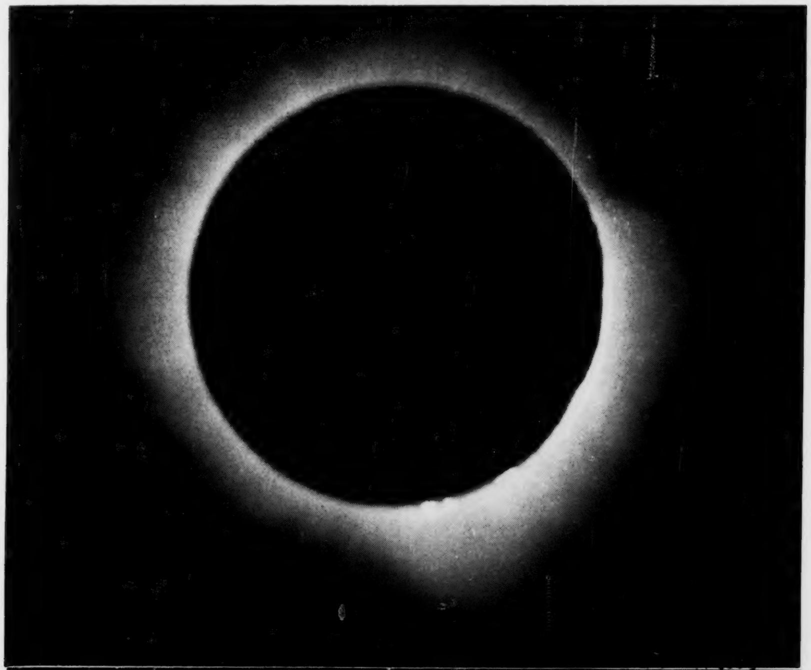
The complete job took almost four years, involving all my spare time from my regular work as head of a major division of the Centro Technico de Aeronautica in Brazil and as consultant to three Brazilian airlines. During the last 10 months of that time I spent, with few exceptions, every night, weekend, and all of Brazil's numerous holidays at the task. The labor of love developed into an exhausting task that I would not want to do again, yet would not want to have missed the unique experience of building these instruments.

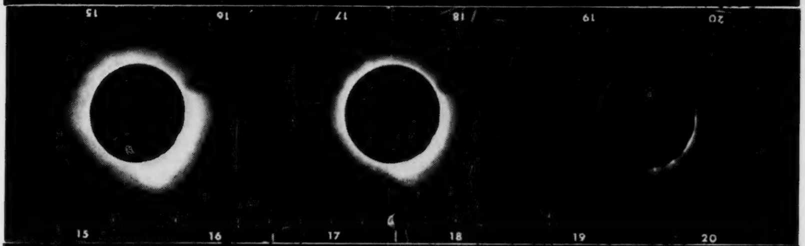
BRADLEY H. YOUNG
P. O. Box 822
Los Altos, Calif.

CORRECTION

On page 217 of last month's issue, at the foot of the finding list of planetaries, the Ring nebula should be listed as NGC 6720, not 6572. This error was pointed out by J. Wheeler, Flushing, N. Y., and by J. Molnar, Jr., Hellertown, Pa.

At three o'clock in the morning, B. H. Young operates the polishing machine, to get the work back on schedule. A full-sized tool is being used, face-down on the mirror, with reduced weighting. The faceted pattern of the polishing lap can be seen through the tool.

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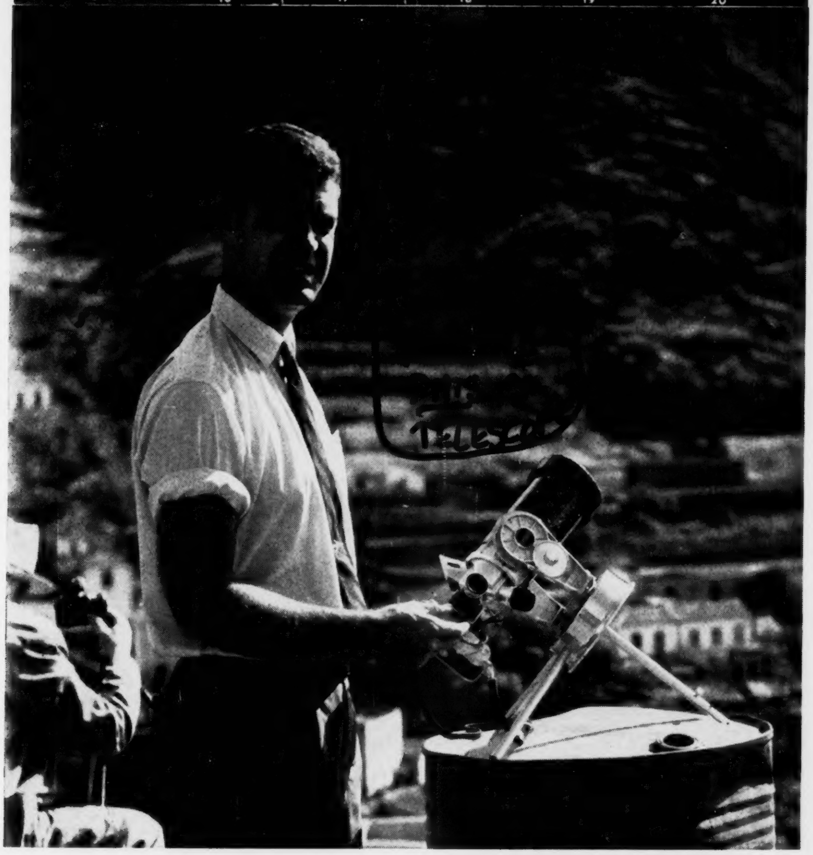


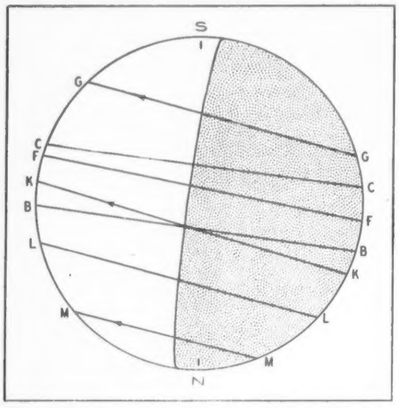
CELESTIAL CALENDAR

Universal time (UT) is used unless otherwise noted.

Occultation of Aldebaran

On the afternoon and evening of March 4th, observers all over the United States will be able to see the first-quarter moon occult Aldebaran. Both immersion and emersion will be visible. The accompanying diagram shows the apparent motion of the star with respect to the moon for several stations in North America.

For observers on the East Coast, the event will begin in evening twilight, and end with the sky fully dark. Farther west the sun will be up, and on the West Coast the occultation occurs in midafternoon. However, Aldebaran's magnitude is 1.1, and it should be possible anywhere to watch the spectacle with a telescope, using the moon to locate the star shortly before the immersion.

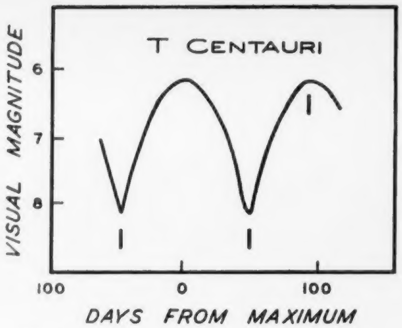


The apparent motion of Aldebaran behind the moon on March 4th, as seen from several American and Canadian stations. The moon's dark part is stippled here.

For a description of how to time an occultation, see page 71 of the December, 1959, Sky and Telescope. That issue also contains the 1960 Occultation Supplement, which shows the geographical locations of the standard stations, gives exact times and position angles for the event, and tells how to derive predictions for one's local station.

In the following timetable, all events take place in the afternoon (p.m.). *Im* indicates immersion or disappearance, *Em*, emersion or reappearance.

Sta.	*Location*	*Im*	*Em*	*Time*
A	Massachusetts	6:41	8:08	EST
B	Montreal	6:38	8:03	EST
C	Washington, D. C.	6:32	8:02	EST
D	Toronto	6:26	7:56	EST
F	Illinois	4:59	6:33	CST
G	Texas	4:40	6:33	CST
H	Denver	3:32	5:01	MST
I	N. M.-Ariz.	3:17	4:45	MST
J	Edmonton	4:00	4:42	MST
K	California	2:07	3:27	PST
L	Oregon	2:21	3:30	PST
M	Vancouver	2:41	3:26	PST



The mean light curve of T Centauri, derived by Leon Campbell from observations by members of the American Association of Variable Star Observers (AAVSO).

T CENTAURI

Late NIGHTS in March provide a favorable opportunity for skywatchers with an unobstructed southern horizon to locate the unusual variable star T Centauri. Now near maximum light, it is bright enough to be found in binoculars, with the aid of a star atlas such as the Skalnate Pleso or Norton's.

In an average cycle, T Centauri varies from magnitude 6.1 to 8.0 and back, over an interval of 90.60 days. Formerly famed as the Mira-type variable of shortest known period, this star is described in the latest Moscow catalogue as an unusually stable semiregular variable. At its brightest maxima it is magnitude 5.5, while some minima are as faint as 9.0.

The variability of T Centauri was discovered in May, 1894, by a British amateur at Gibraltar, Lt. Col. E. E. Markwick. He was comparing star maps with the sky, using 5-power binoculars in a systematic search for new variables, when he noted that the star was $1\frac{1}{2}$ magnitudes fainter than charted.

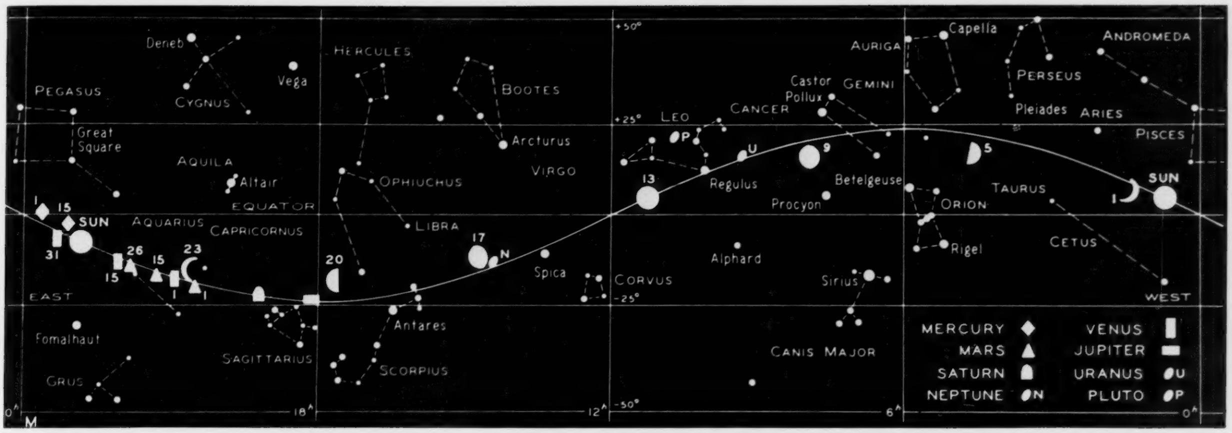
This southern variable star reaches about the same meridian altitude in Norfolk, Virginia, or Tulsa, Oklahoma, as at Gibraltar. Its 1950 co-ordinates are $13^h\ 38^m.9$, $-33°\ 21'$, about five degrees northwest of 2nd-magnitude Theta Centauri.

VARIABLE STAR MAXIMA

March 6, R Serpentis, 154615, 6.9; 6, T Centauri, **133633**, 6.1; 7, R Canum Venaticorum, 134440a, 7.7; 9, R Ophiuchi, **170215**, 7.9; 13, T Eridani, **035124**, 8.0; 16, RR Scorpii, **165030**, 5.9; 22, R Cancri, 081112, 6.8; 23, RU Cygni, 213753, 8.0; 24, R Leonis, 094211, 5.8; 26, RS Herculis, 171723, 7.9; 28, U Octantis, **131283**, 7.9; 29, S Carinae, **100661**, 5.7.

April 4, R Geminorum, 070122a, 7.1; 6, RS Scorpii, **164844**, 7.0.

These predictions of variable star maxima are by the AAVSO. Only stars are included brighter than magnitude 8.0 at an average maximum. Some, but not all of them, are nearly as bright as maximum two or three weeks before and after the dates for their maxima. The data given include, in order, the day of the month near which the maximum should occur, the star name, the star designation number, which gives the rough right ascension (first four figures) and declination (bold face if southern), and the predicted visual magnitude.



THE SUN, MOON, AND PLANETS THIS MONTH

The sun, on the ecliptic, is shown for the beginning and end of the month. The moon's symbols give its phase roughly, with the date marked alongside. Each planet is located for the middle of the month or for other dates shown. All positions are for 0^h Universal time on the respective dates.

The sun will be partially eclipsed on March 27th for observers in parts of Australia, the South Pacific Ocean, and Antarctica. Maximum obscuration will be 70.5 per cent of the sun's diameter.

Mercury may be seen low in the western sky after sunset the first few days of March, but is soon lost in the sun's glare. Inferior conjunction occurs on the 10th, after which the planet will be in the morning sky, too near the sun to be seen readily during the rest of the month.

On the morning of March 25th, Mercury will be occulted by the moon for observers in the northeastern part of North America. Predictions of this event were given in the Occultation Supplement, December, 1959, issue of Sky and Telescope. The planet is listed as Z. C. 4001 in the table.

Venus is a morning object, rising in the southeast about an hour before the sun at the beginning of the month. At this time its magnitude is −3.3. By the end of March, Venus will be lost in the dawn.

Earth reaches heliocentric longitude 180° on March 20th at 14:43 Universal time. This is the March equinox, when spring begins in the Northern Hemisphere and autumn in the Southern.

The moon will be totally eclipsed on the morning of March 13th, as described on page 227 of last month's issue. Observers in North and South America are well placed geographically for viewing this eclipse. The moon begins to enter the umbra of the earth's shadow at 6:38 UT, and totality commences 63 minutes later. Mid-eclipse is at 8:28, and totality ends 47 minutes later. Last umbral contact occurs at 10:18 UT.

Mars is a morning object in Capricornus, rising about $1\frac{1}{2}$ hours before sunup, but still difficult to find in the southeastern sky. Its magnitude this month is +1.4.

Jupiter rises about $1\frac{3}{4}$ hours after midnight, local time, on March 15th. It is in Sagittarius, about 15° west of Saturn, and of magnitude −1.7. A telescope shows its flattened disk, 37″.0 in equatorial diameter. The moon will pass 5° north of the giant planet on the morning of March 20th. Jupiter's western quadrature occurs on the 22nd.

Saturn is in Sagittarius east of Jupiter this month, rising three hours before the sun in midmonth. It is then at magnitude +0.8, its telescopic disk 14″.3 in diameter. The ring system is 36″.1 in extent, and tipped 24°.1 to our line of sight. On the morning of March 21st the moon will pass 4° north of Saturn.

Uranus is a 6th-magnitude object in western Leo, readily located with the aid of the finder chart published on page 191 of the January issue. The planet is well up in the east at sunset and easily viewed with field glasses, though a good telescope is needed to show the 3″.9 disk.

Neptune rises about two hours before midnight, local time, and is an 8th-magnitude planet in eastern Libra. On the 15th it is at right ascension 14^h $27^m.6$, declination −12° 41′ (1950 co-ordinates). In larger telescopes it presents a tiny greenish disk, 2″.5 across.

Pluto is in Leo, on March 15th at 10^h $44^m.3$, +21° 44′ (1950). This 15th-magnitude object is very difficult to identify visually except with special charts or marked photographs.

W. H. G.

MOON PHASES AND DISTANCE

First quarter	March 5, 11:06
Full moon	March 13, 8:26
Last quarter	March 20, 6:41
New moon	March 27, 7:38
First quarter	April 4, 7:05

March	Distance	Diameter
Apogee 6, 2^h	251,300 mi.	29′ 33″
Perigee 19, 7^h	229,800 mi.	32′ 19″
April		
Apogee 2, 22^h	251,400 mi.	29′ 32″

MINOR PLANET PREDICTIONS

Iris, 7, 9.8. March 7, 12:56.4 −14-24; 17, 12:48.6 −13-46; 27, 12:39.6 −12-52. April 6, 12:30.3 −11-47; 16, 12:21.7 −10-37; 26, 12:14.7 −9-30. Opposition on March 30.

Nemausa, 51, 10.3. March 7, 13:10.3 −4-46; 17, 13:05.4 −3-07; 27, 12:58.5 −1-17. April 6, 12:50.6 +0-34; 16, 12:43.0 +2-15; 26, 12:36.8 +3-36. Opposition on April 4.

Flora, 8, 9.9. March 27, 14:18.6 −4-01. April 6, 14:10.6 −3-02; 16, 14:01.1 −2-03; 26, 13:51.0 −1-12. May 6, 13:41.6 −0-34; 16, 13:33.9 −0-15. Opposition on April 21.

Vesta, 4, is observable in binoculars during March; see page 254 of last month's issue for predictions.

After the asteroid's name are its number and the approximate visual magnitude expected at opposition. At 10-day intervals are given its right ascension and declination (1950.0) for 0^h Universal time. In each case the motion of the asteroid is retrograde. Data are supplied by the IAU Minor Planet Center at the University of Cincinnati Observatory.

MINIMA OF ALGOL

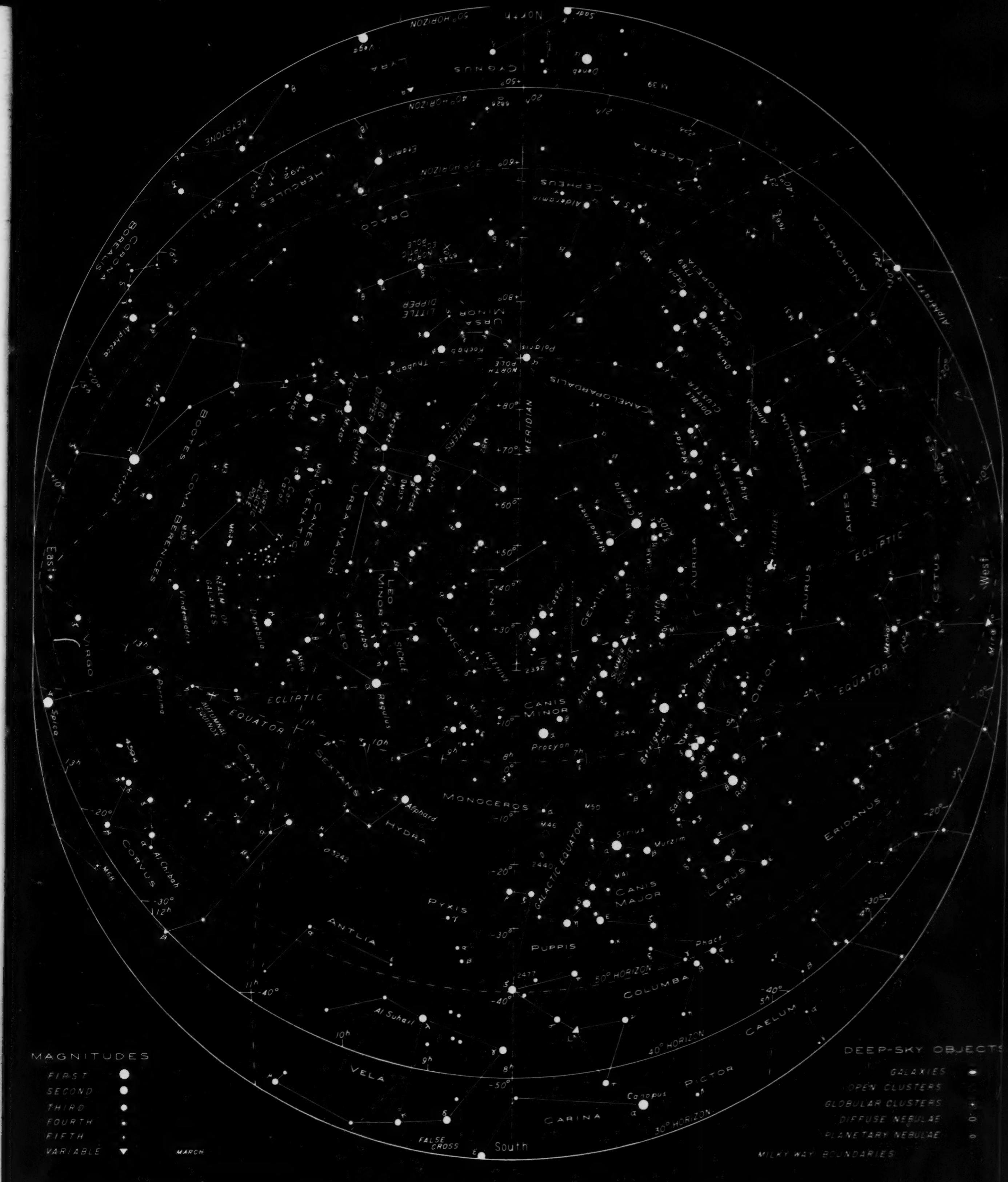
March 3, 0:26; 5, 21:15; 8, 18:04; 11, 14:54; 14, 11:43; 17, 8:32; 20, 5:21; 23, 2:10; 25, 23:00; 28, 19:49; 31, 16:38.

April 3, 13:27; 6, 10:16; 9, 7:06.

These minima predictions for Algol are based on the formula in the 1953 *International Supplement* of the Krakow Observatory. The times given are geocentric; they can be compared directly with observed times of the star's least brightness.

UNIVERSAL TIME (UT)

TIMES used in Celestial Calendar are Greenwich civil or Universal time, unless otherwise noted. This is 24-hour time, from midnight to midnight; times greater than 12:00 are p.m. Subtract the following hours to convert to standard times in the United States: EST, 5; CST, 6; MST, 7; PST, 8. If necessary, add 24 hours to the UT before subtracting, in which case the result is your standard time on the day preceding the Greenwich date shown. For example, 6:15 UT on the 15th of the month corresponds to 1:15 a.m. EST on the 15th, and to 10:15 p.m. PST on the 14th.



STARS FOR MARCH

The sky as seen from latitudes 30° to 50° north, at 9 p.m. and 8 p.m., local time, on the 7th and 23rd of March, respectively; also, at 7 p.m. on April 7th. For other dates, add or subtract ½ hour per week.

Parts of the old constellation Argo Navis are now near the southern horizon. Highest is Puppis, the Stern of the Argonaut's ship. Vela the Sails is to the east. Farthest south is Carina the Keel, visible from the southerly parts of the United States.

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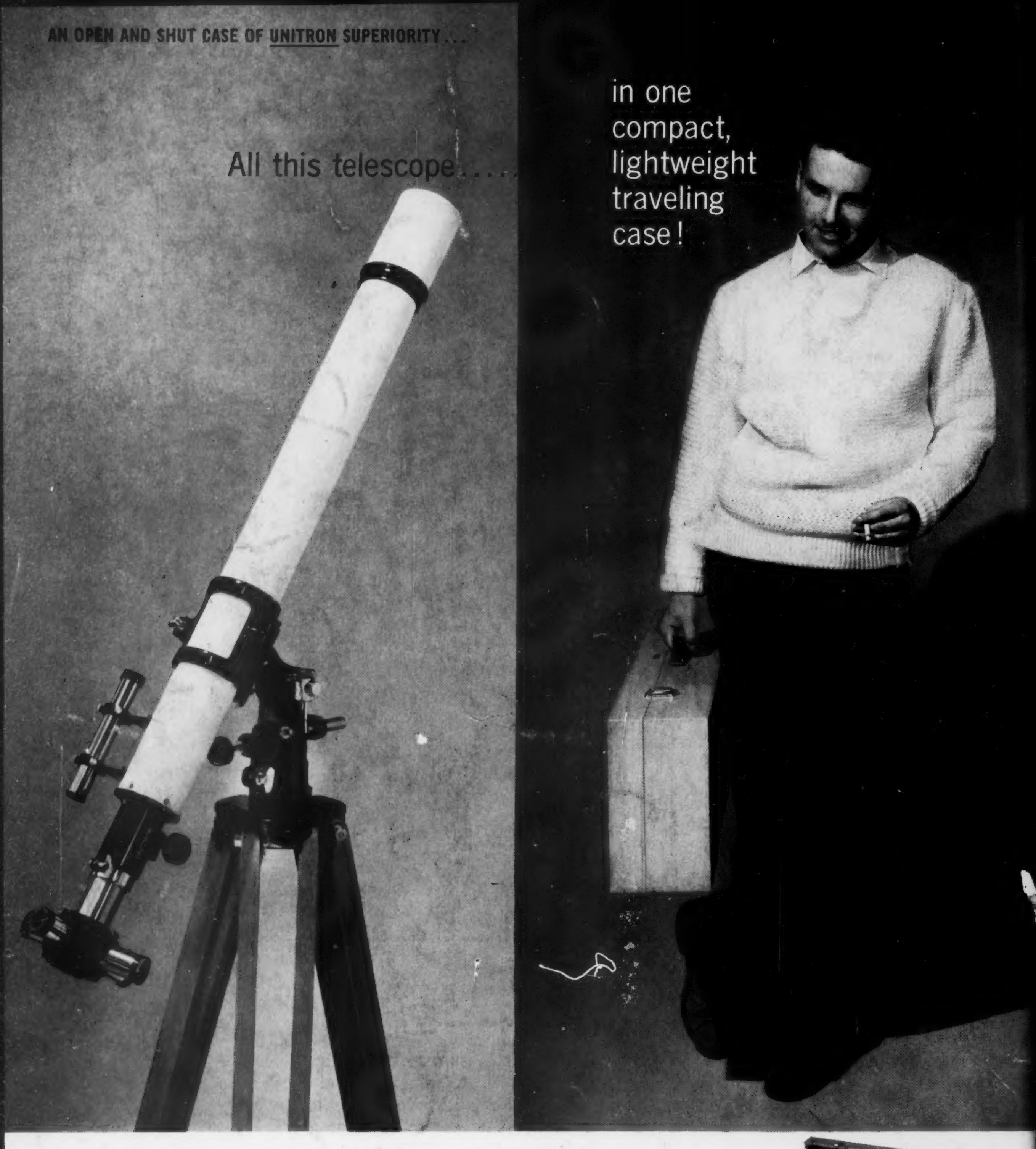

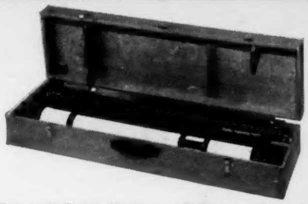

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SEE PAGES 290 AND 291 FOR MORE ABOUT UNITRON.

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